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Publications of the Disaster Prevention Research Institute of Kyoto University

The Disaster Prevention Research Institute publishes the results of its research activities in annuals (in Japanese) and bulletins. The annual is published at the end of an academic year, April to March. One volume of the bulletin, corresponding to an academic year, is divided into five parts. Each of the first four parts includes several papers, and the fifth part comprises the abstracts of papers published by staff members of the Institute in the academic year.

Discussions and the request for a copy of a paper should be addressed to the authors at the Disaster Prevention Research Institute, Kyoto University Gokasho, Uji, Kyoto, Japan.

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Site Selection and Aseismic Considerations

By Soji YOSHIKAWA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 1-4 (in Japanese).

Abstract

The recent and sudden development of industry in Japan has required a search for new construction sites where various problems of aseismic design are involved. Especially in connection with input force no accurate studies have been made from the engineering seismological point of view. In this paper, some probable methods are discussed for making aseismic study of newly developed construction sites. In the first place, strong ground motion during earthquakes has to be inferred from the observation of micro earthquakes and ground structures, where no records of big earthquakes are available. These may be supposed to be possible when many observational data on them are accumulated. It has been found from recent investigation that the mechanism of earthquakes in a given region has a difinite regularity, even though they may not be directly connected with the active faults in Japan. In view of above, more effective strong-motion records may be obtained when attention is given to getting seismologically supported data.

Secondly, the seismic zoning map in Japan has been drawn according to earthquake damage to wooden houses and traditional structures; however, it is rather debatable to apply this to modern designed structures such as high buildings and nuclear power stations which have suffered no damage so far. Several probable methods both theoretical and experimental are discussed in this case. The necessity of micro-zoning in Japan is also discussed because many experiences of earthquake damage have been proved to be closely concerned with local characteristics of the earthground.

Techniques for the observation of strong motion caused by earthquakes have to be determined more effectively in regard to the methods and measure points in order to be utilized for aseismic design. The influences of geological structures on the input force are also discussed by taking into consideration the observational results of micro earthquakes and geophysical prospecting.

On the Near Surface Effects of the Seismic Waves from Explosions and Local Small Earthquakes

By Junpei AKAMATSU, Kojiro IRIKURA and Kazuko MATSUO

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 163-173 (in Japanese).

Abstract

Seismic waves of short periods are affected by the small structures throughout their propagating paths and are seriously affected by near surface structures. In engineering seismology these near surface effects of seismic waves are interpreted as the multiple reflections of SH waves under the assumption of horizontally stratified parallel layers, and are applied for the vibrational characteristics of the grounds. There are, however, significant points to be considered, such as scattering or lateral reflections and/or refractions caused by the lateral inhomogeneities of the topographycal structures, etc..

By observing the seismic waves from explosions and from local small earthquakes around the Amagase Crustal Movement Observatory, the vibrational characteristics of the ground were estimated and compared.

The explosion seismograms being transient, mode separations are attempted. The group arrivals of various modes are identified using multiple filter technique which shows the instantaneous amplitude distribution and the instantaneous phase angle v.s. frequencies. Observed Rayleigh waves are dispersive, and have their maximum amplitude in 2–3 cps which gives the minimum group velocities. The phase velocities of these modes are calculated using time windows of various lengths. Most of the dispersions are normal, but in relatively higer frequency ranges they become irregular. In these ranges the waves are affected by the local geology and topography. In the transverse component, relatively pulsive wave groups are observed in 2–3 cps after S arrivals; these are considered Love waves.

In the amplitude Fourier spectra of the S-parts of the local small earthquakes there are peaks in 2–3 cps. From analyses by the multiple filter technique these are not pulsive but continuous wave groups. The phase angles and the directions of the principal axis of the orbital motions of this mode are mainly SH type, but change to Rayleigh type or SV type after several seconds. It is considered that the multiple reflections of SH waves are affected by the localities.

The reported value of the ratio Vp/Vs of the waves from local small earthquakes is 1.72, but in the case of the waves from explosions, Vp/Vs is about 1.9–2.0. Therefore local near surface effects must be considered when the incident angles or the particle motions of the waves in higher frequency ranges from local small earthquakes are discussed.

Underground Structure and Seismic Wave Velocities at the Uji Campus of Kyoto University

By Choro KITSUNEZAKI

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 175-195 (in Japanese).

Abstract

1. This paper presents the results of seismic experiments carried out by the author at the Uji Campus of Kyoto University since 1964, putting special emphasis on the relation between the distribution of seismic velocities and geological conditions. Geological data are supplied from boring surveys, planned by the technical staff of the university to explore foundation geology for architectual construction, and from well drilling for water supply in and near the university campus.

2. The fundamental geological construction in this area is as follows:

(1) The base (A) is paleozoic strata consisting of chart, slate and sand stone.

(2) The thick layer (B) covering the base is the lower diluvium, called "Osaka group", consisting of unconsolidated gravel, sand and clay. This layer dips to the west with an inclination of about 10°.

(3) The thin layer (C), 7-20 m thick, exists with horizontal layering near the ground surface, covering over the lower diluvium. This is unconsolidated clay and gravel, considered as the upper diluvium or lower alluvium. There is unconformity between C and D.

3. Detailed seismic logging regarding P and S waves is practised to a depth of about 20 m. This corresponds mainly to C, and perhaps partly to D. By this logging, it is ascertained that the gravel layer existing in restricted depth, about 2 to 8 m, shows considerable anisotropic character regarding both P and S wave. The seismic wave velocities propagating in a horizontal direction are about twice those in a vertical direction.

4. As to the seismic refraction method, the simple analysis method proposed by K. Seya gave satisfactory results in conversion from the structure analyzed on the assumption of isotropy to real anisotropic structure.

5. Severe attenuation of SH refraction (head) wave in this area appears to be caused by such a special velocity distribution, as SH wave velocity (0.8 km/s) of the upper layer (2 to 8m in depth) is higher than that (0.45 km/s) of the lower. (Velocity value: horizontal propagation)

6. The present seismic and geological data can serve as a primary step to further development of research regarding the relation between ground motion, excited by earthquakes, and ground condition.

The Characteristics of Vibrations Produced by a Horizontal Point Force in a Multi-layered Elastic Ground

By Michiyasu SHIMA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 197-212 (in Japanese).

Abstract

The vibrational characteristics of multilayered elastic ground are investigated theoretically in the case of the stationary harmonic vibration of the surface of that ground. Then, we consider the vibration generated by a horizontal point force on the surface.

Integral expressions for the displacement fields are derived by using a technique applied first by N. A. Haskell to seismological problems. These expressions are transformed to complex integrals on the complex plane for ease of computation. As the points of computation of the displacement are near the origin, the branch line integrals become comparable with the contribution from the pole.

The numerical results are compared with the spectra in a case where an infinite train of harmonic plane waves is vertically transmitted to the surface layers. In every case, the horizontal point source whose frequency characteristic is constant with respect to the displacement is on the surface and the amplitudes of displacement are calculated from the surface to a depth equal to three times the thickness of the surface layer under the source. The peaks and dips of the amplitude spectra at each point become clearer with the increase in depth, and the shape of the spectral curve approximates to that in the case in which the harmonic plane waves are normally incident upwards to the surface layer. The first peak of the curve at the points of the bottom medium and the intermediate layer corresponds to the fundamental mode of the surface layer consisting of the two layers, and the first peak at the points of the upper layer corresponds to the fundamental mode of the upper layer. It is clear from these results that when the observation points in the vibration test are in the bottom stratum and the intermediate layer, the characteristic frequency of the ground in earthquakes can be inferred from the amplitude spectrum of the vibration test.

On Earthquakes in Southern Kyūshū

By Keizō YOSHIKAWA and Shunzō NAKAMURA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 27-34 (in Japanese).

Abstract

This paper is composed of 3 articles.

(1) Epicenter distribution in the Kyūshū district.

The hypocenters of the earthquakes in and near Kyūshū during 1967-68 after "The Seismological Bulletin of J. M. A." are plotted on a map, and this shows that the hypocenter distribution is divided into three zones which run parallel to each other in a NE-SW direction. The depths of the epicenters in the west zone are less than 20 km, those in the east zone are less than 70 km, and the deep earthquakes more than 100 km only occur in the center zone, which the West Japan Volcanic Belt runs on.

(2) The seismic underground structure of the Kyūshū district.

From the observation results of the "Ebino earthquake swarm" at the seismic observation stations in Kyūshū, time-distance curves for P and S waves are obtained, and the seismic crustal structure is estimated from them. According to them, the average velocities of P and S waves in the 2nd layer in the Kyūshū district are 6.0 km/sec. and 3.6 km/sec., respectively, and the thickness of the 1st layer will be 5.4 km when the velocity of P wave in it is 4.3 km/sec.. But the arrival times at each station show some deviations from the time-distance curve; especially, it is often found that the arrival times of S waves which pass under active volcanoes are delayed.

(3) Seismic activity in and near Amami-Ōshima

3-component electro-magnetic type seismographs, in which Tp=1 sec., Tg=1/15 sec. and M_{max}=1,000, were set up at Naze city in Feb. 1969. During Feb. 9-April 30, they recorded 10-30 earthquakes a day, and S-P times for most of these earthquakes were less than 12 sec.. From these results we must recognize that seismic activity in and near Amami-Ōshima is energetic.

Volcanic Crustal Deformations (IV)

— On the Observations of Crustal Deformations at the Hiyamizu Station —

By Tsuneo ETO

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 41-48 (in Japanese).

Abstract

In addition to repeated precise geodetic levelings, continuous registrations of volcanic crustal deformations by means of Sassa type extensometers, horizontal pendulum-type tiltmeters and a recording water tube tiltmeter were carried out at the Hiyamizu station near the Sakura-jima-volcano.

The analyses of two horizontal components of the Sassa-type extensograms during the period from 1963 to 1967 suggested the horizontal strain rate of 1.6×10^{-6}/year of extension in the direction N 14°W and 1.0×10^{-6}/year of contraction in the direction N 76°E. The vector diagram of the ground tilts observed with two components of the horizontal pendulum-type tiltmeters showed a mean tilting rate of 2.3″/year of dip to the southwest during the period from 1962 to 1968.

A comparison of amounts of secular change of ground tilts in the W 14°S dip direction observed with the precise levelings, the recording water tube tiltmeter and the horizontal pendulum type tiltmeter during the period from 1963 to 1967 revealed ground tilts of approximately 1″, 3″ and 9″ in angle respectively in the same direction.

An Investigation on the Volcanic Micro-earthquakes and the Volcanic Explosion of Sakurajima Volcano (1)

— On the Classification of the Volcanic Explosion and the Explosion after the Lava Ascending —

By Kiyoshi NISHI

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 49-62 (in Japanese).

Abstract

Volcanic explosions at the Minamidake crater of Sakurajima volcano are classified systematically into six types, according to the mode of occurrence of volcanic micro-earthquakes for about two hours before and after each explosion. The definitions of these explosion types are as follows:

D I type explosion: for about two hours before and after the explosion there occur scarcely any such micro-earthquakes.

D II type explosion: for about two hours before the explosion there are scarcely any earthquakes, but immediately after the explosion such earthquakes begin to occur.

D III type explosion: for about two hours before the explosion earthquakes occur, but after the explosion there are scarcely any earthquakes.

D III′ type explosion: the mode of occurrence of the earthquakes is nearly the same as that of the D III type explosion, but the frequency of the earthquakes before the explosion increases with time remarkably till the occurrence of the explosion itself.

D IV type explosion: for about two hours before and after the explosion earthquakes occur.

D IV′ type explosion: the mode of occurrence of the earthquakes is nearly the same as that of the D IV type explosion, but the frequency of the earthquakes before the explosion increases with time remarkably till the occurrence of the explosion.

From analyzing the data from Sept. 1963 to Dec. 1968, the following results are obtained;

1) The same type explosions are often repeated. This may be because each type of explosion results from the conditions of the volcanic vent and the energy supply from the reservoir.

2) Large explosions are mostly of the D IV or D IV′ type.

3) After the formation of the lava-lake in the crater, D I type explosions occur frequently. Judging from the difference in arrival time between the seismic wave and the sonic one, the origins of the D I type explosions seem to be shallower than those of the other type explosions. This is ascertained from the incident angle of the explosion earthquakes.

In addition, the process of the occurrence of D I type explosions is investigated.

The Deep Earthquake of June 22, 1966 in Banda Sea: A Multiple Shock

By Kazuo OIKE

Bulletin of the Disaster Prevention Research Institute, Kyoto University,
Vol. 19, Part 2, No. 158, November, 1969, pp. 55-65 (in English).

Abstract

The body waves of the deep earthquake which occurred in the Banda Sea region on June 22, 1966, were recorded by the long-period seismographs of the WWSSN, and they showed very peculiar aspects compared with the waveforms of normal deep earthquakes. In the record of the P wave at each station two successive P phases were clearly distinguished.

The fault plane solutions of the first P phases, P_1, and the second, P_2, showed nearly the same pattern. Accordingly P_2 phase was not the stopping phase that is to be expected from the moving source.

The relation between the positions of the two foci and the difference between their origin times were determined from the distribution of the difference between the arrival times of the two P waves. The results showed that the second focus was situated on one of the nodal planes of the first shock at a distance of 22 kilometers in the direction of N170°E along the horizontal plane. The difference between the origin times was found to be about 4.8 seconds.

The superposition of the two impulsive waves synthesized from the impulse response of the crust-instrumental system and the amplitudes calculated by assuming the fault plane solutions, the relation of the focal positions and the ratio of the seismic moments of the two shocks, gave the theoretical waveform for each station. They showed very good coincidence with the observed records. The most appropriate ratio of the seismic moments was 4.0.

Comparing the amplitudes calculated from the point source of shear dislocation with the observed ones, the seismic moments of the first and second shocks were found to be about 1.4×10^{25} and 5.6×10^{25} dyne·cm, respectively.

Investigation of Microearthquakes
— On Seismicity —

By Michio HASHIZUME

Bulletin of the Disaster Prevention Research Institute, Kyoto University,
Vol. 19, Part 2, No. 159, November, 1969, pp. 67-85 (in English).

Abstract

Concerning the hypocenters of microearthquakes observed by the seismological network attached to the Tottori Microearthquake Observatory of the Disaster Prevention Research Institute of Kyoto University, an outline of the observed data, the method of hypocenter determination, and a seismicity map are presented.

About 1500 hypocenters of microearthquakes were determined using the data obtained at five seismological stations from August 1964 to June 1968. About 98% of them were determined within the standard deviation 0.15 sec by the method of hypocenter determination discussed in this paper. The seismicity map is shown in Fig. 7. and Fig. 11.

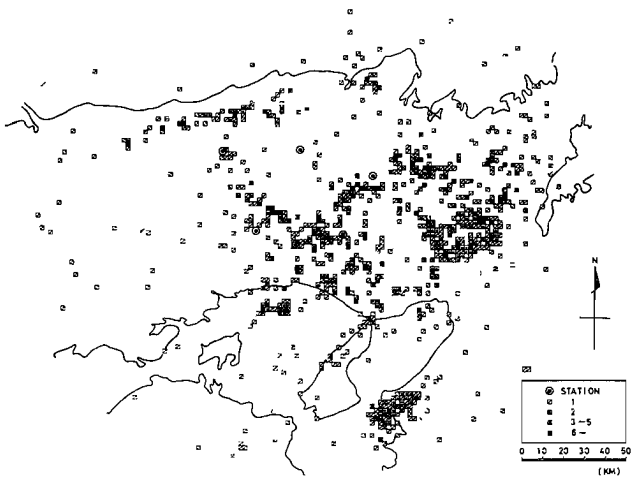

Fig. 7 Seismicity map of the northwestern part of the Kinki and the eastern part of the Chugoku districts. The end of shore line is nearly the limited boundary on determining the hypocenter.

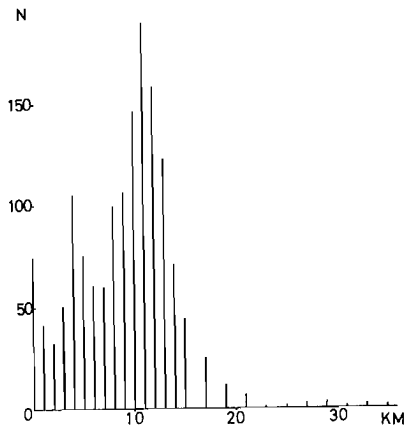

Fig. 11 Histogram of frequency (N)-depth.

Investigation of Microearthquakes
— On the Accuracy of Hypocenter Determination —

By Michio HASHIZUME

Bulletin of the Disaster Prevention Research Institute, Kyoto University,
Vol. 19, Part 3, No. 160, February, 1970, pp. 1-17 (in English).

Abstract

Hypocenter determination is most accurate when two parameters, crustal structure and origin time, are fixed. In this case the crustal structure can be assumed as the first approximation, and the origin time is determined independently by using S-P time and preliminarily calculated Poisson's ratio. Although the accuracy of such hypocenter determination varies according to the given conditions, the accuracy is better, and the seismicity can be discussed more uniformly than those obtained by other methods.

When the origin time can not be independently determined, that is, the S phase can not be read at any station, the accuracy of the origin time and focal depth is not good, for general usage in the study of microearthquakes, and uniform seismicity can not be studied.

The method of hypocenter determination which depends on crustal structure and origin time unknown cannot be used for the study of microearthquakes.

The error of origin time by independent determination is not large as compared to the error by other methods and does not affect the accuracy of hypocenter determination very much.

The accuracy of hypocenter determination by setting the approximated crustal structure is not good far outside the network if the difference between the real and the assumed structure is great. But the structure can be revised by using the determined hypocenter.

One method is to search for a model to make the standard deviation in determining hypocenter minimum. Another method is to observe earthquakes independently outside the network and to make the O-C minimum. Crustal structure can be studied by means of microearthquakes as well as by explosion seismology.

The Time Variation of the Focal Mechanism and the Activity of Earthquake Swarms

By Kazuo OIKE

Bulletin of the Disaster Prevention Research Institute, Kyoto University,
Vol. 19, Part 4, No. 165, March, 1970, pp. 21-35 (in English).

Abstract

Earthquake swarms which have occurred in Japan since 1962 have been investigated. Their origins are found to be situated in the volcanic region; this coincides with the results of Mogi's investigations.

The swarms are generally separated into three stages. These three stages correspond to the foreshocks, main shock and maximum aftershock respectively in the sequence of normal shallow earthquakes of the foreshock type.

The pressure directions of the shocks change with time corresponding to the time variation of the activity of the swarm.

Notes on a Long-Period Seismograph System with RC Network

By Takeshi MIKUMO

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970. pp. 121-132 (in Japanese).

Abstract

Characteristics of a long-period seismograph system with RC network are described. The system consists of an electromagnetic seismograph of Press-Ewing type, resistance-capacitance double integrating network, DC amplifiers, and a rectilinear ink-writing galvanometer with a long-duration recorder. This study includes theoretical evaluation of the behavior of a condenser-shunted pendulum, of the transfer characteristics of the RC network, and of the overall system response. Experimental procedure by applying a calibration signal with steady-state or step function current to an auxiliary coil leads to determination of the amplitude and phase responses of the system to the ground acceleration and hence the ground displacement. The impulse response of the system and theoretical waveforms for the incidence of impulsive P and SV waves at the base of the crust, are computed for later discussions. Examples of the seismograms from a distant earthquake and aftershock sequences are also presented.

On the Mechanism of the Earthquake Swarm at Mt. Yakedake on November 8, 1968

By Kazuo OIKE

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 133-140 (in Japanese).

Abstract

The mechanism of the earthquake swarm that occurred at Mt. Yakedake on November 8, 1968, has been studied. The swarm began at 01^h30^m and terminated at 14^h51^m. Forty three shocks were recorded at Kamitakara by the vertical component seismograph for the observation of micro-earthquakes. The frequency distribution of the P~S interval times of the swarm corresponds to one of the four peaks in that distribution which were observed at the station during four months before the occurrence of the earthquake swarm.

The foci of these shocks have been determined from the P~S times observed at the near micro-earthquake observation stations. They are confined within a small volume whose dimension is about 500 meters.

The time variation of the S/P, which means the ratio of the maximum amplitudes of P and S waves, have been investigated. The push-pull distributions of the initial P motions have also been studied. The results show that the focal mechanism changes in relation to the activity of the earthquake swarm and seems to approach the stationary state at the end of the swarm. It is supposed that the occurrence of the main shocks disturbed the stress field around their foci and had much influence upon the mechanism of the smaller shocks.

This earthquake swarm is separated into four sequences. In the first sequence a large shock of M=3.4 occurred in isolation. A main shock of M=3.3 and many aftershocks took place in the second sequence; a main shock of M=3.1 with some foreshocks and aftershocks occurred in the third one; and a swarm of some smaller shocks occurred in the fourth one. This variation of the characteristics of the activity of each sequence seems to be related to the development of the fractures in the focal region.

Long-Period P Waveforms and the Source Mechanism of Intermediate Earthquakes

By Takeshi MIKUMO

Journal of Physics of the Earth, Vol. 17, No. 2, December, 1969, pp. 169-192
(in English).

Abstract

Long-period P waveforms have been analyzed to interpret the source mechanism of four intermediate earthquakes with magnitudes of $6.0 \sim 6.5$ and focal depths between 100 and 200 km.

The synthetic seismograms appropriate to each recording station have been constructed to compare with observed records, on the basis of moving dislocation models with various parameters, including the fault length and width, the amount of dislocation, its time dependence and the fracture velocity, taking into account the combined effects of wave propagation in the earth and of a recording instrument. General features of the observed waveforms do not differ greatly from those for a double-couple point source, but the comparison with synthesized waveforms at a number of stations indicated seismic moment of order of $1.6 \sim 3.0 \times 10^{26}$ dyne·cm, and also probable ranges for some other source parameters on the assumed source. The bounds of the stress-strain drop, the released strain energy, and of efficiency of seismic wave radiation at the source were also discussed.

The Study of Strain Steps Associated With Earthquakes

By Shuzo TAKEMOTO and Michio TAKADA

Journal of the Geodetic Society of Japan, Vol. 15, Nos. 2.3, 1969, pp. 68-74
(in Japanese).

Abstract

Strain steps associated with earthquakes have been observed with super-invar-bar extensometers at the Iwakura, Amagase and Donzurubo Observatories for earthquakes of magnitude 3.2–7.9.

The stability of these instruments for vibration was confirmed experimentally by two methods using one of the super-invar-bar extensometers installed at the Amagase Observatory.

Strain step amplitude dependance upon distance seems to be $R^{-2.4}$, and if M is the smallest earthquake magnitude from which strains of the order of 10^{-8} may be expected at a distance of R km, the empirical relationship between M and R can be shown in the following form:

$$M=2.2 \log R-10.6$$

Considering the ultimate strain of the earth's crust and based on the elasticity theory of dislocations, the fault length is related to the earthquake magnitude by the following equation,

$$M=2.2 \log L-8.4$$

where L is the fault length in cm.

The Direction of the Particle Motions of Local Small Earthquakes

By Tamotsu FURUZAWA and Kojiro IRIKURA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 149-161 (in Japanese).

Abstract

The surface particle motions were obtained in the horizontal and vertical planes to identify the P, SV and SH phases of local small earthquakes. The data used in this study were from 26 local small earthquakes (P-S time: 1～4 sec) and were obtained by temporary observation at the Amagase Crustal Movement Observatory in August of 1969. Records of the events on magnetic tapes were filtered with the analog variable filter in both positive and negative times and digitized with an A-D converter. The low-pass and high-pass filters were used to emphasize the signals and to attenuate the high frequency noises and micro-seismic waves. The P waves' particle motion from 3 explosions at a distance of 5 km indicated the direction of the known source. The inclination angles were clockwise about 1°～7°. As a method of separating P waves, SV waves and SH waves, pure longitudinal and transverse seismograms were produced from the NS and EW components according to the azimuth angle θ determined by the particle motion of the P waves' first motion. The use of the polarization angle of S waves is usually restricted by the fact that the particle motions of S waves are nonlinear for incident angles greater than $\sin^{-1}(V_s/V_p)$. The epicenter distance of the local near earthquakes is comparable to the focal depth (about 10 km depth) in this region, and therefore it is possible to utilize the polarization angles of S waves. On the assumption that most of the earthquakes which occurred in this region have approximately the same focal mechanism, the direction of polarization and the sense of the first pulse of the S waves were examined by means of superposing the epicenters of all events. In this region, the horizontal component of the maximum pressure of both noticeable and micro earthquakes is considered by several authors to lie in an EW direction. The result of our analysis was that the distribution of pushpull of P waves can be explained by this model on the whole, but a bundle of earthquakes in a westerly direction shows an inverse sense. The sense of the first motion of SH waves and polarization angle cannot be definitely indicated in this model. Though SH/P and SH/SH, the ratio of mean level of Fourier Spectra of P, SV and SH phase are distinguished depending on the azimuth angle, we cannot sufficiently explain them in this model. The data used in this paper are insufficient to discuss the focal mechanism in detail.

Determination of the Effectiveness of Landslide Preventive Engineering Works in the Kushibayashi Landslide Area, Using the Electrical Resistivity Method

By Shin'ichi YAMAGUCHI, Yuji TAKADA, Atsuo TAKEUCHI and Akira NAKAGAWA

Bulletin of the Disaster Prevention Research Institute, Kyoto University, Volume 19, Part 2, No. 156, November, 1969, pp. 25-42 (in English).

Annuals, Disaster Prevention Research Institute, Kyoto University, No. 13 A, March, 1970, pp. 463-477 (in Japanese).

Abstract

Repeated testing of the effectiveness of landslide-preventive engineering works, both during their contruction and after their completion, can give data that will be useful in three ways: 1) to know the effectiveness of each stage of construction as it is completed; 2) to make any changes necessary in that stage or in the next stage; 3) to improve the design of future projects.

Such testing, using the electrical resistivity method, was carried out at various stages of landslide-preventive engineering works at Kushibayashi, Ogoto-Cho, Otsu City, Shiga Prefecture.

The results were highly useful, especially in connection with problems of drainage of underground water.

On the Kushibayashi Landslide Area

By Shin'ichi YAMAGUCHI, Yuji TAKADA, Atsuo TAKEUCHI
and Akira NAKAGAWA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 12 B, March, 1969, pp. 25-45 (in Japanese).

Abstract

The Kushibayashi landslide at Ogoto town in Shiga prefecture, occurred on 22 June 1967. There had been a drought from the middle of April to the end of June 1967.

Landslide usually have some proximate cause, such as rain-fall melting of snow, or earthquakes. A landslide under drought conditions was unusual, so we made geophysical surveys in this landslide area.

These surveys were; electrical; geological; soil mechanical; landslide displacement; and underground water.

These investigations showed that the main cause of this landslide was the flom of underground water in this area. It had weakened this landslide's bedrock and soil mass reducing the safety factor of the landslide mass to a critical condition. Thereupon a trifling proximate cause triggered this landslide mass.

Hence, in the first active stage, this landslide mass moved rapidly, and in the second active stage the mass crept slowly.

Observation of Inclinometers at Landslide Areas

By Yuji TAKADA and Toshifumi KONISHI

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 531-539 (in Japanese).

Abstract

Using inclinometers the writers studied variations of surface inclinations in a landslide area to get information for fore casting landslide occurrence and estimating dangerous areas in a landslide area.

We studied the variation values of the surface inclinations at Kamenose landslide area as measured from April 1966 to March 1967. At the end of this term, tension and compression cracks occurred and surface movement had accelerated gradually. In this landslide area, inclinometers were set at 24 points which were selected as the most suitable points to study surface phenomena, and measurements were taken once a week during this term. When we compared the surface inclination with the horizontal displacement at any given point, the points where the surface had changed were recognized by a horizontal displacement of over 1 meter. Of course no change of surface inclination could be recognized where there were no horizontal displacement points. The variations of surface inclinations in the landslide during 2 months before the soil movement occurred are shown by the following simple equation: $I=An^{k}$, where A and K are constants, n is the number of days from the day when a surface inclination had changed to the day when that surface inclination could not be measured because of the occurrence of cracks near the measuring points; or else because change had stopped.

From the variations of surface inclination, we calculated the constant values of A and K at each measuring point, then plotted these A and K values, shown as a horizontal axis and vertical axis respectively, to find the relation between them.

On the graph these points fall on a straight line with some distribution. From the date of surface inclination measured by inclinometer at another landslide area where there had been no soil displacement, the constants of A and K were calculated and were plotted on the graph. These points on the graph are differed from the points which were calculated for the Kamenose landslide area, except in the case of areas which had not moved.

From this study we suppose that the forecasting of a landslide movement by inclinometer observations, using A and K, is feasible, and that inclinometer measurements made once a week provide sufficient data.

On the Usefulness of Electrical Resistivity Surveys on the Fractured-Zone Type Landslides

By Atsuo TAKEUCHI

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp 479-498 (in Japanese).

Abstract

The usefulness of electrical resistivity surveys at Tertiary type landslide areas has been shown by Dr. Takeda. So I have considered to what extent electrical resistivity surveys could be useful at other types of landslide area. If the usefulness of electrical resistivity surveys could be shown for other types of landslide area, many valuable data could be obtained to make clear the displacement mechanisms of landslides, and effective preventive engneering works could be also, expenses for investigations and preventive engineering works would be much reduced.

At present, at landslide areas other than the Tertiary type, electrical resistivity surveys are little used. So I have examined the usefulness of on electrical resistivity survey at Fractured-zone type landslide areas which are of very frequent occurence, after those of the Tertiary type. Landslide areas examined were: the Wade landslide area, belonging to the Mikabu green rocks zone; and the Choja landslide area, belonging to the Chichibu zoning Kurosegawa tectonic line. The results of these electrical resistivity surveys were the following valuable information:

1. Outline of the form of the bedrock and slide layer
2. Existence and condition of underground water
3. Some hypothesis as to the landslide displacement mechanism
4. Estimate of effectiveness of landslide preventive engineering works emphasising underground water drainage

Hence, it is clear that the usefulness of electrical resistivity surveys Fractured-zone type landslide areas has been established.

Accordingly, when landslide investigations are to be made, an electrical resistivity survey should be carried out at the first step in any such investigations. After getting the above-mentioned information, further landslide investigations and landslide preventive engneering works can be carried out more effectively and at less expense.

A Study of the Shattered Zone Type Landslide
— The Character of Deposits from Landslide Areas in the Mikabu Terrain —

By Takahiko FURUYA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 517-529 (in Japanese).

Abstract

The author has surveyed the geology and geomorphology of some areas which are notorious for landslide in the Mikabu terrain of Shikoku. The Mikabu terrain is composed of metamorphic form of the basic volcanic rock and its tuffs which lie between the Sambagawa and Chichibu belts; and these metamorphic rocks are distributed along the Mikabu tectonic line. The metamorphic rocks are so-called Mikabu greenrocks. The Mikabu greenrocks area has the typical shattered zone type landslide areas of Tairadani, Kage, Nuta, Gotokudani-gawa, Wada, Matsukino, Tatewari, Sawatari and others. The surveyed areas from among them are; Nuta, Gotokudani-gawa, Wada, Matsukino and Tatewari.

The Nuta landslide areas is in contact with the Mikabu tectonic line, and the geology of this location changes gradually from the black schist of the Sambagawa belt to the Mikabu greenrocks. Gotokudanigawa, Wada, Matsukino, and Tatewari landslide areas are composed of Mikabu greenrocks only.

The topography of this Mikabu greenrocks area is classified in the early maturity stage, and the mountain slope is generally steep. However, gentle slopes also remain on the mountainsides in places, and those gentle slopes often contain landslide areas.

The common features of the above-mentioned landslide areas are reported through their geology, bore hole data, and slope morphology. These common features are summarized as follows;

1) The deposits of the landslide areas consist of angular and sub-angular detrital materials with small guantities of clay and sub-rounded gravels.

2) These deposits are in the brooks of the landslide areas, and the thickness of these deposits is rather thin relation to the lenght of the landslide slopes.

3) The geomorphlogical features of the landslide areas and their suroundings are convex slopes with recognized break on the slope.

4) The above-mentioned features of the landslide areas, show geomorphological processes which are closely related with their geological condition; and geology is not always a factor of landslide areas.

A Visco-Elastic Theory of the Deformation of a Confined Aquifer

By Yoshiaki FUKUO

Bulletin of the Disaster Prevention Research Institute, Kyoto University,
Vol. 19, Part 1, No. 150, August, 1969, pp. 1-13 (in English).

Abstract

It is usually said that the subsidence of a ground surface results from the consolidation of the soil layer caused by the depression of the pore pressure. Much study has been given to explaining the mechanism of this subsidence on the basis of the elastic theory of consolidation, in the hope of preventing damage. But many investigations indicate nonelastic deformation of soil. So the author has considered this deformation from the viewpoint of linear visco-elastic theory and derived the following fundamental equation:

$$\frac{\partial \Theta}{\partial t}=\frac{k}{\rho g}(\mathfrak{L}+2\mathfrak{M})\nabla^2\Theta=k\nabla^2\varphi$$

where g is the acceleration of gravity; ρ and φ are the density and piezo-metric head of the confined ground water; k and Θ are the permeability and dilatation of the soil skeleton; and $\mathfrak{L}$ and $\mathfrak{M}$ are the operations with respect to time differentiation defined from the visco-elasticity of the soil skeleton.

A theoretical example was given for the deformation of a confined aquifer of the Voigt type $\mathfrak{L}+2\mathfrak{M}\equiv(\lambda+2\mu)\left(1+c\frac{\partial}{\partial t}\right)$ caused by pumping up ground water from a small well at a constant rate Q after a certain time $t=0$ in the aquifer which stretches infinitely in lateral direction and has a uniform thickness b.

We got the exact solutions of the fundamental equation

$$\varphi=\frac{Q}{2\pi bk}\left[K_0(r^*)+\sum_{n=1}^{\infty}\frac{1}{n!}\left(\frac{r^*}{2}\right)^n K_n(r^*)\left\{1-e^{-t^*}\sum_{m=0}^{n-1}\frac{t^{*m}}{m!}\right\}\right]$$

$$\Theta=\frac{\rho gQ}{2\pi(\lambda+2\mu)bk}\left[\sum_{n=0}^{\infty}\frac{1}{n!}\left(\frac{r^*}{2}\right)^n K_n(r^*)\left\{1-e^{-t^*}\sum_{m=0}^{n}\frac{t^{*m}}{m!}\right\}\right]$$

where $K_n(r^*)$ is the modified Bessel function; t^* and r^* are defined by non-dimensional time t/c and radius $\sqrt{\frac{\rho g r^2}{ck(\lambda+2\mu)}}$, respectively, and $(\lambda+2\mu)$ is the elastic part of the Voigt model; and c is the time constant of retarding elasticity.

Internal Waves in Lake Biwa (I)
— The Responses of the Thermocline to Wind Action —

By Seiichi KANARI

Bulletin of the Disaster Prevention Research Institute, Kyoto University,
Vol. 19, Part 3, No. 161, February, 1970, pp. 19-26 (in English).

Abstract

In this preliminary observation of internal waves in Lake Biwa, the longitudinal inclination of the thermocline due to wind with a northerly component and the initial stage of free oscillation after that wind has ceased are observed. This observation was carried out from September 17 to 23, 1968, with three single-layered subsurface buoy-stations at Suga-ura in the northern part of Lake Biwa.

The three stations were set in this bay at intervals of 200 meters from each other.

Each subsurface buoy was 5 m below the surface, and a thermister thermometer was fixed at a depth of 17.5 m, where the thermocline was found at the time when the buoy-stations were set.

From the records of the subsurface buoy-stations, we found large temperature variations in the thermocline layer, involving two types of dominant periodic changes of water temperature. One has a period of 56 hrs, and the other has a period of 10 hrs.

These temperature variations were compared with the decomposed wind velocities observed at Hikone and at the Ado-river during the same period.

It was found that the 56-hr periodic change corresponds to the longitudinal internal seiche of the north basin, caused by the northerly component of the wind which had blown over the lake during an interval of about 24 hrs; and the 10-hr periodic change corresponds to the transverse internal seiche under geostrophic effects. The 56-hr period just coincides with the one calculated for a simplified two-layered lake without rotation, but the later period of 10 hrs does not agree so well with the calculated period.

However, the calculated period of the transverse internal seiche without rotation has larger discrepancy than that of the transverse internal seiche under geostrophic effects.

The ratio of the mean breadth to the diameter of the inertia circle for the transverse internal seiche is about 42. This ratio is about six times that for the longitudinal internal seiches without geostrophic effects.

This fact means that in contrast to the longitudinal internal seiche, in which the inertia circle may be restricted by the width of the lake, the transverse internal seiche has no restriction in the longitudinal direction.

Distribution of Land Water in South-East Asia and Taiwan (I)

By Setsuo OKUDA, Ryuma YOSHIOKA and Yasushi KITANO

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 12B, March, 1969, pp. 213-229 (in Japanese).

Abstract

South-east Asia and Taiwan are under tropical and subtropical climate and easily erodible geological conditions; and in these regions, active fluvial processes of denudation, mass transport and rapid sedimentation are bringing about a serious topographic change and causing various types of damages to the inhabitants.

One of the authors, S. Okuda, participated in the scientific survey team for topographic change and natural disasters in Malaya, Sumatra, Java, Bali and Taiwan, and took charge of geomorphologial investigation and water sample collection.

In Malaya, side erosion along meandering necks in the Perak River and landslides in Cameron Highlands were surveyed as examples of most serious damages in this country.

In Sumatra, a rapid swifting of a meandering river near Rantau was surveyed as an example of an active fluvial process; and a thermal stratification in Lake Toba was observed in order to investigate the heat budget in a tropical lake.

In Java and Bali, we surveyed active erosion in a wide mountainous region covered with fresh volcanic eruption, which brings about terrible mass wasting at the base of the mountains and leads to rapid extension of deltas in river mouths.

In Taiwan, we surveyed mass transport through rivers and landslides in mountainous regions occurring on large scales and caused by steep slopes of mountains and heavy rains with typhoons.

About one hundred water samples collected from many rivers and lakes in these countries were analysed by Y. Kitano and R. Yoshioka in order to investigate the relation between geological conditions and weathering processes from the view point of geochemistry. Characteristic distributions of specified elements corresponding to special geological conditions and relations between element concentrations and eroding processes were found in several drainage basins.

On the Relation between Physical Geomorphology and the Science of Natural Disasters

By Setsuo OKUDA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp 23-26 (in Japanese).

Abstract

The need for a new branch of geomorphology, "Physical Geomorphology," is stressed in order to promote a more complete study of geomorphic cycles from the view point of physical science and system analysis, to permit more reasonable human adjustment to landform change.

As a transitional stage in the development of Physical Geomorphology, the progress of dynamic and quantitative geomorphology and mutual assistance between these two branches are desired in order to stimulate physical study of geomorphological phenomena and simulation analysis of human reactions to landform change.

The present state of study in various branches of geomorphology is outlined, and the cooperation of many branches is emphasized to develop the new discipline for the synthetic progress of geomorphology.

The possible contribution of Physical Geomorphology to disaster prevention research is discussed with reference to the still transient stage of development of that new branch.

The most important contributions are:

(i) Direct study on the relation between geomorphological processes and disaster phenomena. For example, the relation between mass wasting process and landslides.

(ii) Study on disaster phenomena caused by the characteristic process producing landforms. For example, land subsidence caused by the structure of deltaic areas.

(iii) Application of new methods in geomorphology to disaster prevention research. For example, application of aerial photo interpretation to disaster damage survey or disaster forecasting.

Frost Heaving and Its Dependence on Heat Flux through a Freezing Front (2)

By Yoshiaki FUKUO and Koichi KITAOKA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 557-564 (in Japanese).

Abstract

It has been pointed out that the frost heave process is intimately connected with heat flux through the soil. For lack of information such as heave rate, moisture flow and temperature gradient while ice lensing is in progress, it may appear that quantitative treatment of the combined heat and moisture flow is not yet possible today. Hence, systematic experimental research is very much needed. We have constructed new instruments for this research and they are in successful operation. Using such experimental data, we have studied the heat balance at the freezing front and the relation between the moisture flow and heat flux at various cooling rates. Fig. 1 shows the result of experiments for soil samples with the indices: 5% in clay, 85% in silt and 10% in fine sand in weight, 50.7% in porosity and 38.1% in water content per dry weight of soil. From these figures we found, as reported previously, the optimum heat flux in relation to moisture flow.

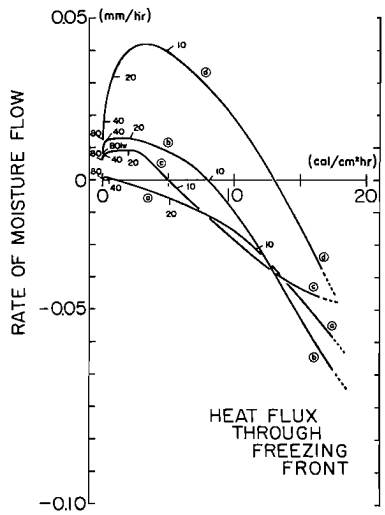

Fig. 1 Correlations between the rate of moisture flow and heat flux through the freezing front. The abscissa gives the heat flux difference between the frozen part and the unfrozen part just above and just below the freezing front. Figures beside the curves represent the time in hours after freezing.

Ground Water Flow Due to Infiltration in Sloping Soil Layers

By Yoshiaki FUKUO

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 565-572 (in Japanese).

Abstract

When rain water infiltrates into the weathering soil layer laid on a mountain slope and reaches the bed rock surface of the slope, ground water flow will be generated on the bed rock surface if the infiltration of water exceeds the downward leakage of water out of the bed rock surface. In this paper, the author has investigated theoretically the development of such a flow due to infiltration.

Suppose that, as a theoretical model, the bed rock surface is an infinite flat plane expressed by $y+bx=0$ where $b\equiv\tan\beta$ is constant inclination, the surface of the soil layer is parallel to bed rock surface expressed by $y+bx=D$ where D is the uniform thickness of the layer and the precipitation and leakage of water are kept at the constant intensities I and L respectively. After a certain time $t=0$ on the semi-infinite region $x\geq 0$, we find a uniform flow which is covered by two free surfaces: the one $\eta_1=-cx$ stretching downstream from the upper limit of leaky bed surface $x=y=0$ with a constant inclination $c\equiv\tan\gamma$ to horizontal surface and the other $\eta_2=\frac{I-L}{\sigma}t-bx$ growing upwardly at a constant rate $(I-L)/\sigma$ where σ is the porosity of soil layer in parallel to the bed rock surface. This flow has a stream function $\Psi=kA(y+ax)$

$$A=\frac{b}{2(1+b^2)}\left[(i-l)+(1-l)-\sqrt{(1-i)^2-\frac{4}{b^2}(i-l)(1-l)}\right]$$

$$a=\frac{b}{2(i-l)(1-l)}\left[(i-l)+i(1-l)+l\sqrt{(1-i)^2-\frac{4}{b^2}(i-l)(1-l)}\right],$$

where k is the permeability of the soil layer and $i\equiv I/k$, $l\equiv L/k$, within the limit of the conditions

$$(1-i)\geq(1-l)\left(1-\tan^2\frac{\beta}{2}\right) \text{ and } i>l.$$

The inclination of the steady free surface η_1 is expressed by

$$c=\frac{b}{2(1-l)}\left[(1-i)-\sqrt{(1-i)^2-\frac{4}{b^2}(i-l)(1-l)}\right]$$

and it will be seen that the angle γ becomes $\beta/2$ when the specific infiltration i is equal to $\tan^2\frac{\beta}{2}$. The frontal line of the steady free surface η_1 will seep at the position in the distance $S=UD\sec\beta/(I-L)$ (U is the horizontal Darcy's velocity of ground water flow $\partial\Psi/\partial y=kA$) downward along the sloping soil surface from the fringe of the rainfall region $x=0$ and $y=D$ at the time $T=\sigma D/(I-L)$ after the wetting front of the infiltration has reached the bed rock surface.

Distribution of Land Water in South-East Asia and Taiwan (II)
— Development of Deltas and Sea Water Intrusion —

By Setsuo OKUDA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 573-586 (in Japanese).

Abstract

In deltaic areas in South-East Asia and Taiwan there are many places where coastal lines are advancing rapidly and sea water is intruding into the land large distances from the river mouths.

Both these phenomena of coastal line advance and sea water intrusion are very important factors in planning social and economic development in deltaic areas, and there is a close relation between the two phenomena.

The author visited Taiwan, Malaya, Thailand, East Pakistan and Indonesia as a member of a scientific survey team sponsored by the Japanese Ministry of Education in 1968 and as a staff member of an ECAFE consultant group on the development of deltaic areas in 1969.

The data about coastal line change are collected from official reports, scientific papers, aerophotos and maps published in the above-mentioned countries. The degree of salt water intrusion into many estuaries and rivers was investigated both by direct field observation and on the basis of official data.

The results are described with maps, and a simple analysis is added for each region, considering fluvial topography, hydrological conditions, and oceanographical conditions. The results of geochemical analysis on river waters in Malaya are added as a continuation to the previous report (I); and the low concentration of HCO_3^-, $Ca^{2+}+Mg^{2+}$ and soluble SiO_2 in river waters through granite drainage basins shows that in this region chemical weathering is not progressing so rapidly, and landslides seem to occur with less frequency than in granite regions in Japan.

Hydrological Studies of Small Mountainous Drainage Basin (II)
— Soil Moisture Conditions of Hillslopes of Weathered Granite Region —

By Kazuo OKUNISHI

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 587-599 (in Japanese).

Abstract

Continuing the former report (Annuals, Disaster Prevention Research Institute, No. 11), the result of the hydrological investigation carried out in the weathered granite region of the Daido River area is described. Soil moisture conditions of the hillslope in bare soil land and in forest land are compared according to the measurement of soil moisture with the neutron scattering method and the thermodynamic potential of soil moisture with a magnetite hygrometer sensor. The soil was more deficient in soil moisture, and fluctuations of soil moisture content and the potential of soil moisture were larger in the bare soil land than in the forest land. The infiltration capacity of the slope surface as measured with a Musgrave-type infiltrometer was about 400 mm/h in the forest land and about 40 mm/h in the bare soil land.

It is shown that the action of vegetation in the forest land changes the coarse-grained soil at depths less than 70 cm. to fine-grained top soil containing organic matter, which enables the soil to contain more water under the same value of suction. Moreover, the well developed litter and humus layers on the slope surface of the forest land absorbs all the rainfall upon it, supplying it gradually to the underlying soil. On the other hand, bare soil land can not keep the litter and humus layers and fine-grained top soil (if any) because of heavy surface erosion. These characteristics of the soil-water system are one of the principal causes of the peculiar erosional conditions of this region in which the heavily eroded bare soil land and forest land having almost no erosion adjoin each other with a discontinuous boundary.

It is shown that the concentrations of Ca^{++}, Mg^{++}, Fe^{++}, Fe^{+++}, HCO_3^-, and soluble silica in the stream water and the ground water at different localities reflect the routes of the water under the ground, and that the stream water can be divided according to its origins into surface runoff, sub-surface runoff, and ground water runoff on a geochemical basis.

Observations of the stream during a heavy shower showed that the peaks in the concentrations of suspended material, discharge, concentration of dissolved matter, and discharge of bed load material differ with each other in their time of occurrence, and occur in this given sequence.

Studies of Internal Waves in Lake Biwa (III)
— On the Measurement of the Vertical Displacement of Waters by Using an Instrumented Neutrally-Buoyant Float —

By Seiichi KANARI

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 601-608 (in Japanese).

Abstract

An instrumented neutrally-buoyant float was used in the observation of the vertical displacement of waters due to internal waves in Lake Biwa, during the period from 2 to 4, October, 1969, at Suga-ura in the northern part of the lake.

During this observation, continuous measurements of temperature variation were also made by a fixed buoystation having six thermister thermometers at depths of 12 m, 15 m, 18 m, 21 m, 24 m, and 27 m.

From the continuous records obtained by the fixed buoystation, the time series of the vertical displacements of waters at the six depths were evaluated by the following equation,

$$\zeta(t)-\frac{T(t)-T_0}{\left\langle \frac{dT(t)}{dz} \right\rangle}=0$$

where $\zeta(t)$ is the vertical displacement of water, $T(t)$ is the variation of water temperature at a fixed depth, $\langle dT(t)/dz \rangle$ is the mean vertical temperature gradients, and T_0 is the initial water temperature.

One of the purposes of this study is to examine the propriety of the above equation which contains the mean vertical temperature gradients introduced conveniently for the instantaneous vertical temperature gradients.

The estimated mean vertical displacement of waters is compared with the continuous record of the vertical displacement of the instrumented neutrally-buoyant float.

In general, the curve of the estimated vertical displacement of waters coincides with that obtained from direct measurement by the instrumented neutrally-buoyant float, but slight differences exist between them. From calibration, we found that these small differences are due to a thermal effect from the electric circuit contained in the instrumented neutrally-buoyant float.

The Late Pleistocene Limnetic History of Japanese Ancient Lakes Biwa, Yogo, Suwa, and Kizaki

By Shoji HORIE

Mitt. Internat. Verein. Limnol., Bd. 17, 1969, S. 436-445 (in English).

Abstract

In Japan there are several ancient lakes which date back to the middle Pleistocene time or even to the Tertiary period. The characteristic features of these lakes are:

(1) The area in which they lie was not glaciated during the Pleistocene epoch. This is most important for comparing the limnetic history of these lakes with that of the younger lakes of northern North America, northern Europe, and southern South America.

(2) These ancient Japanese lakes are, however, located near mountains in which cirque glaciation took place, at least during the Wisconsin glacial stage.

(3) The limnetic history of ancient lakes is affected by two main factors: climatic changes and crustal deformation. Often the latter especially alters lake basin morphology. Because such morphological deformation changes the proportion between the trophogenic and tropholytic layers and also the volume of the hypolimnion, the typology of the lake changes. We must have many different kinds of information in order to separate the effects of these two factors on paleolimnology.

(4) As the circulation pattern of lakes, which forms the basis of a lake typology, is controlled by temperature, glacial and interglacial ages must have shifted the lacustrine climatic zonation back and forth. Particular attention must be paid to lakes located in the transitional zone between two circulation patterns, such as that between dimictic lakes and warm monomictic lakes, since the alternation of lake typology in this area by climatic shift is very likely. Both lakes Biwa and Yogo are near this transition.

After examining various kinds of sedimentary records in these lakes, I reached to following conclusion. The Japanese ancient lake most sensitive to change of climate seems to be Yogo-ko, which occupies a tiny closed basin and is of less advanced eutrophic lake type. It changes its type readily toward greater eutrophy or toward mesotrophy and leaves distinct records in its sediments. If we select such lakes from the standpoint of limnology and geomorphology and carry out an intensive study of their paleolimnology, we can hope to decipher more accurately the climatic events of the past.

Asian Lakes

By Shoji HORIE

Eutrophication: causes, consequences, correctives. Washington D. C., National Academy of Sciences. 1969, pp. 98-123 (in English).

Abstract

In this paper, the writer has described the unstableness of lake trophy as it is easily changed by interruptions during a lake's ordinary evolution; such interruptions are: climatic change, crustal movement, and vulcanism. He has tentatively grouped the eutrophication features into two classes, that is, local eutrophication and global eutrophication. A combination of these two phenomena is probably being observed by us now. Whereas oligotrophy and eutrophy alternate with each other as long term variations and are reversible, sapropellization, or human fertilization, seems to be an irreversible factor just like a disharmonic lake in which restricted species of limnoorganisms develop extensively. Such sapropellization is outside the category of lake eutrophication.

Furthermore, the writer has made a general review of the eutrophication features of Asian lakes, especially those of Japan. On the basis of ancient lake studies, he gives examples supporting the above idea, that is, we are now witnessing only more or less temporary features of these lakes during their overall limnetic history.

Some Considerations on the Behavior of Sediment in the Daido River

By Kazuo ASHIDA, Yoshio MURAMOTO, Hirotake IMAMOTO,
Yuichiro TANAKA, Shuji NARAI and Tetsuo UENO

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 187-197 (in Japanese).

Abstract

This paper describes the behavior of sediment in the Daido River, a typical alluvial stream carrying a large amount of sediment load, since the main part of the geological structure of its mountainous catchment consists of much-weathered granite. The area of its drainage basin is 189.7 km^2. The average sediment yield is estimated at $10^5 m^3$/year, most of which comes from the erosion of non-vegetation land, the area of which is about 20 km^2. Therefore, the average erosion depth is about 5 mm/year. A recently recorded flood occurred in 1953, when a large amount of sediment (about $4 \times 10^6 m^3$) was produced by the fall of the mountain-side and most of this sediment was deposited in the flood plain. The characteristics of this disaster are discussed with relation to the geographical features.

Sediment transportation in the Daido River was calculated by using Brown's formula from 1924 to 1959. The results showed fairly good agreement with the observed volume of sediment deposited in the Ōmine reservoir, which was located downstream and which is now part of the Amagase reservoir due to the construction of the Amagase dam.

Grain-size distribution of the sediment was examined along the river course from the estuary to the upstream and at the various places on the hill-side. Grain-size distribution at the hill-side is rather similar for the whole drainage basin. Grain-size distribution on the river bed can be obtained by exclusion of the small-size part of the distribution at the hill side.

The distribution of the concentration and grain-side of the suspended sediment and the structure of the turbulence were observed in 1969 flood.

From these observations it was revealed that the fall velocity of the max. grain-size of the suspended sediment is approximately equal to the shear velocity, and the averge grain-size distribntion is nearly eqnal to the distribution of the part smaller than max. grain-size of the suspended material in the sediment yielded at the hill side.

This fact suggested that the rate of the wash load may be estimated from the bed material load and the grain-size distribution at the hill side.

Studies on Fluvial Processes of Stream Channels (1)
— Experiments on the Deformation Process of Alluvial Channels —

By Kazuo ASHIDA, Yoshio MURAMOTO, Shuji NARAI
and Kiyoshi SHIOIRI

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 243-260 (in Japanese).

Abstract

For the regulation and stabilization of rivers it is necessary to be able to forecast the plane deformation of stream channels and the variation of bed configuration. The prediction of the fluvial processes of rivers at the high flow stages is especially important in the prevention of river disasters.

For laboratory work on this problem we set up a large alluvial channel 130 m in length and 7.5 m in width. This paper describes the procedures and the various results of our experiments to date. The experiments were conducted in the alluvial channel with a straight stream groove of trapezoidal cross section of bottom width 100 cm and bed slope 1/200 at discharges of 7.5 and 15.0 l/s. The bed material of the channel was river sand with a median diameter 0.61 mm and standard deviation of the diameters 2.62.

To reveal the channel processes and the mechanism of channel deformation, detailed measurements of hydraulic and sediment factors were made under both drained and running conditions at several time intervals of a flow duration. On the basis of observations of bed profiles, water surface slopes, plane forms of stream channels, and properties of bed materials, the channel was divided into three reaches: upper, middle and lower stream reach; and the variations of mean velocity, shear velocity and channel resistance in each reach with time were discussed. In the upper stream reach, which is characterized as a region of channel degradation, the self-armoring of the channel bed and the regime state were observed. In the middle and the lower stream reaches, which are regions of channel aggradation, prominent bank erosion and alternating bars in the initial stage of the duration, and channel meandering developed in the final stage. In particular, we have discussed the geometrical properties and the bebaviors, as these played an important role in the deformation of the channels and the development of channel meandering.

A Study on Suspended Sediment Transportation Under Non-equilibrium Conditions

By Kazuo ASHIDA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 261-270 (in Japanese).

Abstract

This paper discusses river bed variation due to suspended sediment which occurs under non-equilibrium conditions.

The rate of river bed variation per unit area is considered to be $W_0|C-Cs|$, when W_0 represents the fall velocity of the suspended particle; C, the actual concentration near the bed; and Cs, the concentration under equilibrium conditions, which may be expressed as a function of W_0 and u_* (shear velocity).

The following equation shows the variation of sediment concentration with relation to distance under non-equilibrium conditions from one equilibrium state (shear velocity u_{*0}) to another state (u_*), assuming the diffusion coefficient to be constant in a section and using the vertical distribution of the sediment concentration in an equilibrium state for the first approximation,

$$\frac{C(x,z)}{C_0(x)}=\frac{1}{1-e^{-Rw_0}}\frac{a(x)}{W_0 C_0(x)}\left\{\frac{m}{m-1}(e^{-Rw_0\frac{z}{h}}-e^{-mRw_0\frac{z}{h}})-e^{-Rw_0}(1-e^{-mRw_0\frac{z}{h}})\right\}+e^{-mRw_0\frac{z}{h}}$$

in which,

$Rw_0=15w_0/U_{*0}$

$m=u_{*0}/u_*$

$\frac{a(x)}{a_0(0)}=\frac{C_0(x)-Cs}{C_0(0)-Cs}=e^{-\alpha\frac{w_0x}{q}}$, $\alpha=\frac{1}{\frac{m}{(m-1)Rw_0}-\frac{e^{-Rw_0}}{1-e^{-Rw_0}}}$, $q=uh$,

$C_0(o)$, and Cs are the equilibrium sediment concentrations near the bed for u_{*0} and u_* respectively.

The diagrams for the above calculation are given in this paper.

The above procedure was applied to an experiment on sedimentation in a reservoir where the suspended sediment has a grain-size distribution, by dividing the grain-size for some grades.

The variation of the concentration near the bed obtained by the calculation showed fairly good agreement with the observed variation.

An Experimental Study on Anti-dunes

By Yuichiro TANAKA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 271-284 (in Japanese).

Abstract

Sand waves usually occur when bed materials are moved by running water, and they give rise to various difficult problems in loose boundary hydraulics. Therefore, many theoretical and experimental studies have been conducted on these problems but many unsolved problems remain.

This paper describes some results of comparisons with many studies by various authors, as well as experimental data (which are given in detail) for the geometrical characteristics of anti-dunes, and the regime criteria for the upper flow regime in an open channel with movable bed obtained by using photographic techniques for the measurements. The results obtained in this study are as follows:

(1) Kennedy's equation gives the best agreement with experimental data for wave lengths.

(2) The propagation velocities obtained by Kennedy, Gradowczyk and the author, when analyzed by various methods give the same results, and these show good agreement with measured results.

(3) The analytical result obtained by the author for wave height can be used with sufficient accuracy for all flow regimes.

The author's experiments show that the effect of grain-size is very important in the occurrence of anti-dunes, and that the region of the flat bed grows wider as the grain diameter of the bed materials increases. Though it may be possible to predict the geometrical properties of sand waves from the mean flow parameters with sufficient accurracy, no theories reported up to this time can systematically explain the mechanism of the occurrence of various bed configurations to include the effect of grain-size in clear physical terms. Hence, further studies will be needed.

Studies on Characteristics of Bed Configurations in Open Channels (2)
— From Experiments by Use of a Closed Channel —

By Shuji NARAI

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 285-298 (in Japanese).

Abstract

To investigate the phenomena of movable beds in open-channel flows, especially transitions of bed configurations and flow resistance, the basic experiments are made using a closed channel with a movable bed.

The characteristics of bed configurations in closed-channel flows are almost identical with the results of experimental observations in open-channel flows. The results obtained in closed-channel experiments are as follows:

(1) Transitions from an initial flat bed to undulating bed forms of ripple-dune type, and their break-down process to flat bed are observed.

(2) The statistical structure of undulating beds is the same as that of open-channel flows.

(3) The flow resistance factor varies with the transitions of bed configurations.

And, then, on the basis of the results of closed-channel experiments, the author considers the mechanisms of the transition process of bed configurations in open-channel flows, as follows:

(1) The first transition process, from the initial flat bed to undulating bed forms, occurs when the mean intensity of bed-load transport is insufficient all over the bed and the bed deforms in resonance with the hydrodynamical instability of the flow.

(2) The second transition process, from undulating bed forms to flat bed or standing wave, occurs when the mean intensity of bed-load transport becomes enough all over the bed.

These considerations are examined through analysis of experimental data by other investigators.

(3) The flow resistance factor of a movable bed shows characteristics of its own, and it has an upper limit value as to undulating bed forms and a lower limit value as to a flat bed.

In the latter part of this paper, additional experiments regarding unsteady flow over a movable bed in a closed channel and some problems of flow resistance of unsteady flows are mentioned.

On Turbulence Characteristics in Curved Open Channels

By Yoshio MURAMOTO and Koichi ENDO

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 311-321 (in Japanese).

Abstract

This paper describes the turbulence characteristics of the longitudinal velocity component in curved flows on the basis of the results of the velocity measurements by a small propeller-type current meter. The measurements were conducted in two kinds of 180° curved open channels, with 50 cm of width, 1/200 bed slopes, and central radii of 50 cm and 150 cm respectively, under conditions of supercritical flows. The variations of the lateral distribution of the mean velocity and the statistical properties of turbulent velocity fluctuations along the channels, such as local intensity, autocorrelation coefficient, length scale and energy spectra of turbulence, were discussed. The results obtained are summarized below.

The local intensity and length scale of turbulence decrease in the curved and the down stream straight reach except in the outer part of an inlet region of a curved reach with smaller central radius. In the outer part of the region, the turbulence intensity greatly increases due to the decrease of the mean velocity. But, the r.m.s. of the velocity fluctuation in the region is no more than that in the upper straight reach, and the turbulence scale diminishes. The reduction in the local intensity and the length scale of turbulence in the reaches is mainly due to the decrease of energy spectral density in a lower frequency range, and the energy spectra at the exit section of the curved reach show a nearly uniform distribution in that range.

On the Geometrical Characteristics of Sand Waves

By Yuichiro TANAKA

Proceedings of the 13th Congress of the International Association for Hydraulic Research,
Vol. 5-1, 1969, pp. 249-255 (in English).

Abstract

It is well known experimentally that the height of sand waves is closely related to relative roughness. As the first step in the investigation of the resistance law in a movable bed channel with a free surface, it is the object of this paper to find the functional relationship between the geometrical characteristics of sand waves and flow parameters. This paper consists of two parts.

(1) Detailed measurements of velocity distribution and pressure distribution of flow on sand waves fixed with cement were made. In these measurements, remarkable periodic changes of velocity could be found. These periodic changes are not considered to be the same as normal turbulence but rather those caused by the formation of sand waves. The author assumed that these periodic changes of velocity are caused by the transverse oscillations of the water surface due to the occurrence of sand waves. The mean length of the alternating bars in straight channels and the meander length of meandering streams could be related to the flow parameters, using the above assumption.

(2) The height of sand waves in the equilibrium state for low flow regimes in open channels is determined by the flow parameters using the equations of motion and contimuity for the fluid and sediments with the small amplitude approximation and the assumption that bed waves propagate without deformation. The analytical result seems to give a reasonable explanation of the variation of the height of sand waves, as the plane bed, ripples, dunes and transition. It seems to suggest that it is possible to explain the variation of the resistance in movable-bed channels.

The above two results are compared with the experimental data obtained from the measurements in both experimental flums and actual rivers, with generally good agreement.

Initial Storage of Rain-water in Runoff Process
— Interception by Trees —

By Yasuo ISHIHARA and Shigeki KOBATAKE

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 69-81 (in Japanese).

Abstract

The mechanism of the interception of rainfall by trees which is the first to occur in a runoff process was studied. Several kinds of trees grown in a mountain area were cut down at their bases, and carried to our laboratory. Each tree was suspended from the ceiling through a load cell to measure the change of its weight due to rainfall interception. The kinds of trees were Pinus thumbergi, Japanese cypress and camellia, each being about 4 meters in height. The experiments were carried out for cases where constant intensities of artificial rain fell suddenly on trees then ceased abruptly. The results obtained by experiments and the theoretical considerations are as follows:

1) The relation between the amount of the water stored on a tree, that is, interception, and the number of leaves on that tree is shown quantitatively to be linear for each kind of tree.

2) The amount of water stored on a tree is constant for one constant intensity of rainfall, and draws exponentially to the maximum value, S_m, for another larger intensity of rainfall.

3) In the unsteady state of the interception process, the equation for storage of rain-water on a tree during the period of rainfall is shown by the following equation, using the equivalent area of tree, A_t, which is concerned directly with the process, and the maximum water storage, S_m.

$$dS/dt = A_t \cdot r + A_t/\alpha \cdot ln(1 - S/S_m)$$

4) In the decreasing state of water storage on trees after rain has ceased, the storage decreases according to the above equation during a period of several minutes after ceasing, and exponentially for the period later than about 30 minutes. During the period from several minutes to 30 minutes after the rain ceases, there exist both the decreasing processes of stem flow and of water drop on leaves.

A Study on Flood Control by Group of Dam Reservoirs (I)
— Utilization of DP and some Incidental Problems —

By Takuma TAKASAO and Kunio SENO

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 83-103 (in Japanese).

Abstract

For optimal flood control by dam reservoirs, a precise forecast of floods (especially, flood hydrographs) is the most necessary matter. But precision in such flood forecasts is now very low. Therefore, we must establish a system that copes flexibly and optimally with all floods, even with insufficient forecasting. Such a system will need a method that can get optimal solutions of flood control for all floods logically, universally and rapidly. It will be very helpful to utilize Dynamic Programming (DP) as such a method.

In this study, we first try a multidimensional DP formulation of a general optimal flood control process considering the correlation of dam reservoirs, the effects of floods from inter-basins, and a multi-point-defense. At the same time, we clarify our purpose of flood control, and establish several types of the evaluation functions to be attached to each evaluating point (point to be defended). Secondly, showing some examples of the computed solutions for some basic types of flood control system by the DP formulation, we discuss the criterion of optimality and the possibility of diminution of the system dimension. Consequently, we find the following results: (1) If a flood control system has only one evaluating point, any convex function of discharge passing through the point is sufficient as the evaluation function for our purpose of flood control. (2) If a flood control system has more than two evaluating points and has uncontrollable tributaries between these points, it is necessary to decide the relation between the evaluation functions. The method of deciding that relation is very difficult. (3) If the evaluation functions are convex functions, most of the multidimensional problems can be changed into some one-dimensional or two-dimensional problems by the two methods. But there are cases in which it is impossible to do so, and in such cases it is necessary to find out some other method to diminish the system dimension.

On the Structure of Turbulence in a River Flow

By Yasuo ISHIHARA and Shōitirō YOKOSI

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 323-331 (in Japanese).

Abstract

It is spectrally distinct that large-eddy motion in a river flow is described by a definite structure. The structure of the large-eddy of a vertical turbulence presented by the authors is a "∩-shaped vortex tube" identical with the horseshoe vortex described by Theodorsen as the standard element of turbulence.

A spanwise vortex tube generated at a high shear layer near a river bed will tend to form itself into a ∩-shaped vortex tube, because the vortex tube is exposed to lift and drag forces due to an interaction between the vortex tube and the mean flow. A ∩-shaped vortex tube slanting downstream and producing a jet-like motion away from a river bed gives a negative contribution to the Reynolds stress and derives energy directly from the mean flow to pass it on to the smaller eddies.

The scale of turbulence can be explained by intervals on the arrangement of the ∩-shaped vortex tube. The intervals of the arrangement are about ten times the depth longitudinally and about two times the depth laterally. This is consistent with aerial observation of surface boil made by Kinoshita. The surface boil is the jet-like motion towards the water surface. One cause of this may be the top part of the elongated ∩-shaped vortex tube or elongated vortex ring similar to a doughnut torn off from the top part of the ∩-shaped vortex tube.

The river flow may be considered in three parts: a mean flow, a set of the ∩-shaped vortex tube, and an ordinary turbulent motion made up of a wide and continuous range of eddy sizes. The smaller eddies may be defined as a multiple arrangement of smaller vortex filaments which cover the surface of the ∩-shaped vortex tube. This suggests the image of the movement of a school of eels in a water flume.

Local Behavior of Open Channel Flow

By Tadashi UTAMI

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 361-372 (in Japanese).

Abstract

The large-scale vortex structure developing above an obstacle in flow has long been recognized as having some relation to local scour. However, the structure of these vortices being three-dimensional, little of it has been made clear.

In this paper, the behavior of a local flow near an abrupt contraction of a rectangular channel is investigated experimentally and analytically for the condition of a laminar main flow.

Experimentally, the flow-visualization method in which small air and hydrogen bubbles are applied as tracers is used successfully to measure the flow pattern and the velocity distribution. That is, photographs are taken of the flow patterns in each section parallel to the channel-bed or side wall, and the axis of the vortex and the directions of the flow are made clear. Further, velocity distribution both upstream and at the contracting cross section are measured to get the boundary conditions for further analysis.

Analytically, the vorticity variation along stream lines is made clear. Because of the difficulty of three-dimensional analysis, however, a two-dimensional model of the flow is constructed to analyse the flow patterns approximately under the assumption that the mass transport from one section parallel to the channel bed to another is reduced to the source or sink line along the contraction wall. The results obtained analytically show fairly good agreement with the experiments.

Information on Inflows and Rule for Releasing Water in System of Reservoirs

By Yasuo ISHIHARA and Masashi NAGAO

Proceedings of the 13th Congress of the International Association for Hydraulic Research, Vol. 1-A, 1969, pp. 543-550 (in English).

Abstract

In Japan, since the storage capacities of reservoirs in a river are relatively small and the variation in the amount of rainfall over a short period is very great, the water flowing into reservoirs sometimes spills over, even for a rainfall of a short period of several days or less. Therefore it is necessary, under such circumstances, to establish a corresponding rule for releasing water in a system of reservoirs according to the character of the variation in runoff during such a short period.

In this study, after examining the seasonal and stochastic characters of runoffs during various periods, it is proposed that the information on inflow to reservoirs should be given by the stochastic and deterministic parts of runoff for the short period under consideration of the seasonal variation. The optimal rule for releasing water in a reservoirs system is shown under the condition that the water available for use becomes maximum when such inputs to reservoirs are applied. The outlines of the results are as follows:

(1) In making a time series from a runoff which varies continuously, a suitable time span for dividing such continuous quantities should be adopted. Further, basis of seasonality, the periodicity of a one-year period can be found remarkably well by taking a suitable unit span for sampling.

(2) The seasonal transition of the runoff series can be given as the time-point when the trend-free time series obtained by striking a moving average with the above-mentioned suitable sampling span crosses the secular trend curve which is obtained by striking a moving average with an arithmetic mean of 365 days.

(3) In order to express the series stochastically, the runoff components should be separated into two parts, the stochastic and the deterministic ones, according to information on the runoff series before the time under consideration; and the method of the separation of each component is shown.

(4) As for the various combinations, such as reservoirs in parallel or in series, the optimal rule for releasing water in a reservoirs system is discussed theoretically under the condition that the expected quantity of water spilling ineffectively over the reservoirs system becomes minimum; and the computational example of two-parallel-reservoirs system is explained. As the results of this computation, it is evident that the system operation due to this approach gives a valuable increment of water use in comparison with the customary individual operation.

Mechanics of the Successive Saltation of a Sand Particle on a Granular Bed in a Turbulent Stream

By Yoshito TSUCHIYA

Bulletin of the Disaster Prevention Research Institute, Kyoto University,
Vol. 19, Part 1, No. 152, August 1969, pp. 31-44 (in English).

Abstract

A saltating single sand particle on a granular bed in a turbulent stream will successively continue its saltation motion when the shear velocity of flow is larger than the critical one for the movement. In this paper, such a saltation motion is defined as successive saltation. A theory of the successive saltation of a single sand particle on a granular bed is proposed on the basis of the equation of saltation motion and the dynamic characteristics of collision between a saltating sand particle and bed sand particles. The theoretical relationships for

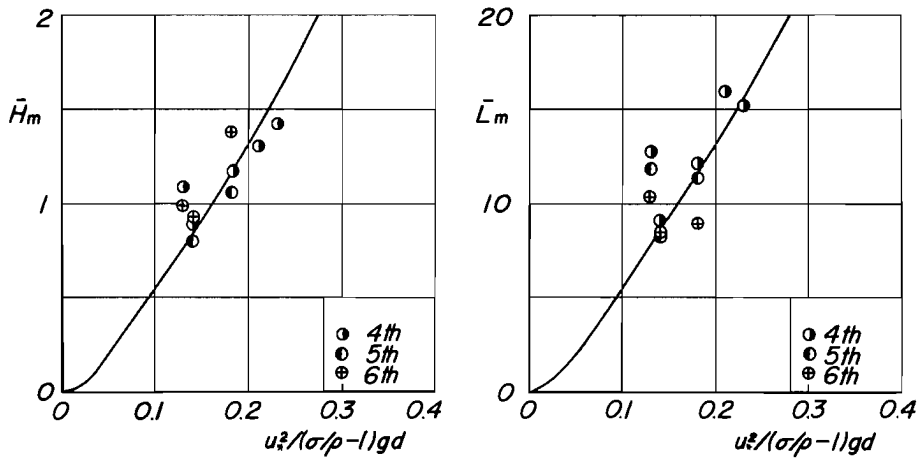

Fig. 1 Comparison between the theoretical curves of height and distance of saltation of a sand particle in stationary saltation and the experimental values.

the saltation height and distance and for their distribution characteristics are in good agreement with the results of the experiments by the author, as seen in Fig. 1.

On the Mechanism of Saltation of a Sand Particle in a Turbulent Stream (2)

— On a Theory of the Successive Saltation —

By Yoshito TSUCHIYA and Toshiki AOYAMA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 199-216 (in Japanese).

Abstract

Most of the saltating sand particles on a granular bed in a turbulent stream have successively continued their saltation motion. In this paper, such a saltation motion is defined as successive saltation. A theory of the successive saltation of a single sand particle on a granular bed is established on the basis of the equations of motion for the saltation and the dynamic characteristics of collision between a saltating sand particle and bed particles. It was concluded that the theoretical relationships for the saltation height and distance and for the distribution characteristics are in good agreement with the results of the experiments. Furthermore, some considerations of the saltation of a cloud of sand particles in a turbulent stream are made by an application of the theory to the saltation motion of sand particles. It was also concluded, as seen in Fig 1, that the theoretical results can well describe the phenomenon of the saltation of sand particles in a turbulent stream.

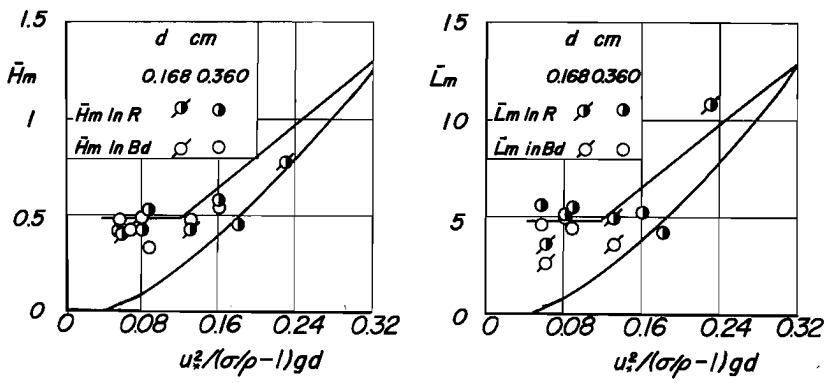

Fig. 1 Variations of saltation height and distance of sand particles in a turbulent stream with dimensionless tractive force in relation to comparison of the theoretical curves of saltation height and distance with the experimental values.

Mechanism of Motion of Sand Grains by Wind (1)
— Experiments on the Initiation for Movement of Sand Grains —

By Yoshito TSUCHIYA and Yoshiaki KAWATA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 217-232 (in Japanese).

Abstract

In studying the mechanism of sand storms, it is neccessary to make clear the mechanics of motion of sand grains by wind in relation to the mechanics of motion of sand grains by water. As the first report, this paper deals with the initiation of movement of sand grains by wind, with the aid of detailed experiments. It was found that there is a wide difference in the dimensionless expression between the dimensionless tractive force, so-called flow intensity and the Reynolds number of sand grains for the initiation of movement of sand grains by water and by wind. Using different kinds of grains with various specific gravities, the effect of the specific gravity of grains on the initiation of movement was considered in a laboratory experiment. It was found as seen in Fig. 1 that the value of the dimensionless

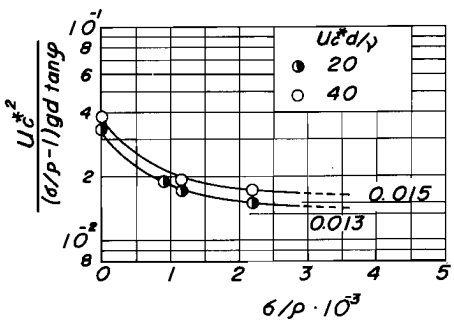

Fig. 1 Influence of relative density of grains to fluid on initiation for movement of grains by wind and by water, calculated by first criterion $p_0=0.5\%/\text{sec}$.

critical tractive force decreases with the increase in the relative density of grains to fluid if the Reynolds number of grains is constant, and would approach a constant when the relative density becomes very large.

Studies on Cnoidal Waves (Eighth Report)
— Experiments on the Horizontal Velocity of Water Particles —

By Yuichi IWAGAKI and Tetsuo SAKAI

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 373-389 (in Japanese).

Abstract

In the third and sixth reports, the applicability of the cnoidal wave theory was discussed by comparison of the experimental results of the wave velocity, wave length, and wave crest height with the theoretical values. This paper, as the eighth report, deals with the horizontal velocity of water particles.

Recently, two methods have been developed to measure the water particle velocity induced by wave motion in a wave tank; one is a method by using hydrogen bubble tracers generated in water at very short intervals by electrolysis, and the other is by a hot film anemometer. The hydrogen bubble tracer method is suitable for measuring vertical distributions of the water particle velocity; and the hot film anemometer is very useful to measure the periodic variations of the instantaneous velocity with time. This paper presents experimental findings on the horizontal velocity of water particles in a wave tank by these two methods; and the applicability of the cnoidal wave theory is discussed by comparison of the results with Stokes' wave theory of the third order and the cnoidal wave and hyperbolic wave theories of the second approximation.

The conclusions obtained are as follows:

(1) From the comparison of experimental results with theoretical curves of horizontal water particle velocity under the wave crest, application limits of the cnoidal wave theory and Stokes' wave theory exist within the range of $T\sqrt{g/h}$ between 9 and 20. And beyond this range, the cnoidal wave theory or hyperbolic wave formula should be applied.

(2) From experimental findings of vertical distributions of water particle velocity under the wave crest and time variations of water particle velocity for a period of waves, this limit obtains when $T\sqrt{g/h}=14.8$.

Basic Studies on Finite Amplitude Standing Waves (3)

By Yoshito TSUCHIYA and Masataka YAMAGUCHI

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 391-407 (in Japanese).

Abstract

Experiments were made regarding the wave pressure of standing waves in the case where wave overtopping exists. When the theoretical findings by finite amplitude standing wave theories were compared with experimental measurements of wave pressure distribution on a wall at wave crest, wave crest heights above the still water level, and time variations of water level and wave pressure on the wall, the following results were obtained.

(1) If the reduction of wave height at the wall by wave overtopping can be estimated, the experimental measurements of the wave crest heights above the still water level agree with the theoretical ones.

(2) While the absolute values for the wave pressure accompanying the wave overtopping decrease compared with the pressures not accompanying wave overtopping, each theory is applicable in this case within the range of the limiting condition for validity, if the reduction of wave height at the wall by the wave overtopping can be estimated. But, when the value of H/H_c is relatively large in which h is the depth of water, H the amplitude in water level variation at the wall and H_c the crest height of wall, the phenomena of the wave pressure are not made sufficiently clear by these theories, even though the reduction of wave height at the wall by wave overtopping can be estimated, because of the change of the characteristics of the wave motion field near the wall.

(3) The rate of wave height reduction at the wall by wave overtopping is estimated by the relation of H/H_c regardless of the wave period within the range of these experiments except for relatively large values of H/H_c.

In addition, the data for the rate of wave overtopping obtained by the authors were compared with the curve of the rate of wave overtopping proposed by Goda. It was found that the correspondence in the comparison is relatively good except for $T\sqrt{g/h} \geqq 14$ and $H_0/L_0 < 0.015$ in which T is the wave period, g the acceleration of gravity, H_0 the wave height of deep water and L_0 the wave length of deep water.

Studies on Closure of River Mouths by Drifting Sand (1)
— The Effects of River Flow on Enlarging of the Flow Area of River Mouths —

By Hideaki NODA and Akira KIMURA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 427-443 (in Japanese).

Abstract

This paper describes the various characteristics of Gorge sections of river mouths such as the flow area, the width and the depth, and the relationship between the minimum cross-sectional area of the river mouths and the maximum discharge of the river flow based on data observed on the Japanese coasts. In addition, the law of momentum is applied to describe the process by which an unstable river mouth will change its shape.

The theoretical prediction of shoaling and closing of river mouths by littoral drift and of enlarging of the flow area by the river flow has not been established as yet, because of the complexities of the hydrodynamic conditions of river mouths and of the difficulties in understanding the mechanics of sediment transport by river flow superimposed by wave action.

As the first step of this study on the mechanics of the closure of river mouths, this paper deals with the problem of enlarging of the flow area of the river mouths by floods. Especially, the effects of river discharge by floods on the flow area of the river mouths are discussed on the basis of the results of frequent hydrographical surveys of some rivers on the Japanese coasts.

The survey shows that the non-dimensional flow area of Gorge sections of river mouths on sandy coasts is a unique function of the non-dimensional width and that a stable cross-sectional area corresponding to the maximum discharge of the river flow exists.

Tsunami Model Experiment of Kochi Harbour

By Yuichi IWAGAKI, Yoshito TSUCHIYA and Shigehisa NAKAMURA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 471-488 (in Japanese).

Abstract

Tsunami disasters and their prevention have recently become important as problems of coastal engineering. In this paper, tsunamis in Kochi Harbour are studied experimentally by the use of a hydraulic model with a tsunami generator of plunger type controlled by a hydraulic servo system.

The model of the harbour was constructed to scales of 1/250 horizontally and 1/100 vertically. The similitudes of dynamic factors are reduced to the scales of current velocity 1/100 and time 1/10 respectively. The model was made of mortar to obtain roughness simulation. The roughness of the model is simulated according to Manning's formula.

After it was determined that the Chilean Tsunami can be successfully reproduced in the model basin, the behaviours of a design tsunami and of regular long waves with various periods in Kochi Harbour were studied both for the harbour's present topography and for a topography after dredging and reclamation. The oscillation characteristics of Kochi Harbour were studied, and it was proved that river flows tend to decrease incidental waves with the present topography. The design tsunami was given as a wave of 30 min in period with crest height 2.4 m above the mean high water level and trough 1.5 m below that of Katsurahama Station which is located at the entrance of the harbour. Time changes of water level and current velocity near the entrance of the harbour were measured in the model of the present topography. The propagation and deformation of a design tsunami in the harbour were also studied. Distributions of the crest height and the wave height of the design tsunami in the harbour were studied in relation to the travel time of the design tsunami. Wave height decreases with the propagation of tsunami by the influence of topographical configuration. The effect of tsunami breakwaters to be constructed at the entrance of the harbour was also studied from the view point of the behaviours of tsunami in the harbour. Generation of an undular bore was found in a model of Kochi Harbour as it might be after dredging. This research will suggest a suitable crown height for the embankment in the harbour.

On the Mechanics of Saltation of a Spherical Sand Particle in a Turbulent Stream

By Yoshito TSUCHIYA

Proceedings of the 13th Congress of the International Association for Hydraulic Research, Vol. 2, 1969, pp. 191-198 (in English).

Abstract

In order to establish the mechanics of sand transport in both water and wind streams, the mechanics of saltation of a single spherical sand particle should first be considered. An approach to establishing the mechanics of saltation including both sliding and rolling motion is presented.

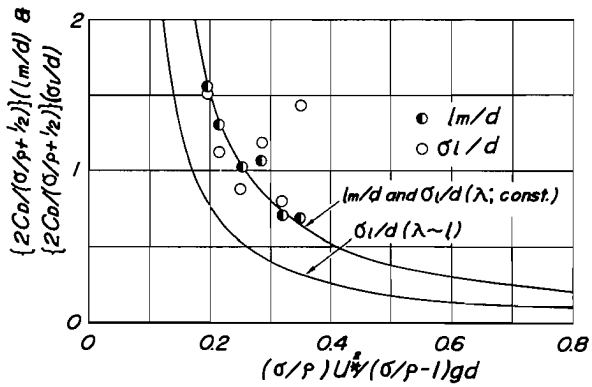

Fig. 1 Comparison between theoretical curves of mean value and standard deviation of rolling distance of a spherical sand particle and experimental values.

It was found from a theoretical approach to describing the rolling motion of a sand particle and the transition from rolling to saltation that the rolling distance decreases with the increase of flow intensity as seen in Fig. 1, that the distribution characteristics of the rolling distance can be expressed as a Poisson process, and that the theoretical relationship of the rolling velocity with slipping is in good agreement with experimental values. It was also found from a theory of saltation taking into consideration the collision of the rolling particle with a bed sand particle that the theoretical relationships of the saltation height and the distribution characteristics are in good agreement with experimental values.

On the Limiting Conditions for the Application of Finite Amplitude Standing Wave Theories Derived by the Perturbation Method

By Yoshito TSUCHIYA and Masataka YAMAGUCHI

Proceedings of the 16th Conference on Coastal Engineering in Japan,
December, 1969, pp. 7-13 (in Japanese).

Abstract

This paper is devoted to the finding of the limiting condition for the application of finite amplitude standing wave theories derived by the use of the perturbation method.

In the first place, the errors for two nonlinear boundary conditions at the free surface, such as the kinematic condition prescribing the particle motion at the free surface and the dynamic condition which describes the pressure at the free surface to be constant on the basis of Bernoulli's theorem by the various approximate solutions of the finite amplitude standing wave theories including Stokes' wave ones by Skjelbreia and Hendrickson are numerically computed for various kinds of wave characteristics expressed by dimensionless parameters and evaluated according to Dean's criterion. Then, by comparing the errors in each theory, graphs expressing the decreasing regions of the errors for two boundary conditions at the free surface are provided.

Next, some experiments in terms of these theories upon a seawall are carried out within the range of $6 \leqq T\sqrt{g/h} \leqq 20$ in which T is the wave period, h the depth of water, and g the acceleration of gravity. Solutions of the various orders for these theories have validity within a certain range of h/H corresponding to each order in which H is the amplitude of standing waves. This is verified by comparing the theoretical results with experimental ones for the wave pressure distribution on the wall at wave crest and wave trough, the wave crest heights above the still water level, and the time variations of water level and pressure on the wall. As a result, a diagram of the limiting conditions for the application of finite amplitude standing wave theories is proposed, within the range of these experiments.

Experiments on Water Particle Velocity of Finite Amplitude Waves

By Yuichi IWAGAKI and Tetsuo SAKAI

Proceedings of the 16th Conference on Coastal Engineering in Japan.
December, 1969, pp. 15-21 (in Japanese).

Abstract

Water particle velocity induced by wave motion is a very important factor in describing the mechanism of wave breaking, wave force acting on offshore structures, the mechanism of suspension and diffusion of sediments by wave motion, and so on. But, because of the difficulty of measurement, this problem has been little investigated experimentally.

Recently, a method of velocity measurement by flow visualization was proposed. It consists of generating hydrogen bubbles in water at regular short intervals by electrolysis, tracing their motion, and thus measuring water particle velocity. Horizontal water particle velocities induced by wave motion in a wave tank were measured by this method. Since, however, this method is not suitable to measuring periodic variation with time, a hot film anemometer was used for measuring periodic variation of the particle velocities. These results are compared with the small amplitude wave theory, Stokes wave theory of the 3rd order and hyperbolic wave formula, which are approximate expressions of the cnoidal wave theory.

Within the range of these experiments, the following conclusions were obtained:

(1) When the values of $T\sqrt{g/h}$ are between 12.0 and 13.0, experimental values fit roughly the values of both Stokes wave theory and the hyperbolic wave formula. When the value of $T\sqrt{g/h}$ is 14.8, the experimental values fit the values of the hyperbolic wave formula rather than those of Stokes wave theory.

(2) Fluctuation of water particle velocity corresponding to the turbulence component can not be found in the record by a hot film anemometer within the range of these experiments, in which the maximum Reynolds number $N_R=137$ and is lower than the critical Reynolds number for transition from laminar to turbulent flow $N_R=160$.

Development of Turbulent Boundary Layers Due to Wave Action

By Hideaki NODA

Proceedings of the 16th Conference of Coastal Engineering in Japan,
December, 1969, pp. 23-27 (in Japanese).

Abstract

This paper describes a method of estimating the characteristics of the turbulent boundary layers developed on smooth and rough bottoms by waves, characteristics such as the bottom shear stresses and the velocity profiles in these layers.

An eddy viscocity assumption analogous to that of Johns is introduced in order to solve the linearized equation of oscillatory motions in the boundary layer. The assumption is that the boundary layer is divided into three parts: inner, intermediate and outer, and that the eddy viscosity in each layer has a different value.

Numerical results of the vertical profiles of the velocity in the wave boundary layer show that Kalkanis's experiments on the velocity profile in an oscillatory turbulent boundary layer seem to be favorably compared with the theoretical prediction derived from the present method, and that the velocity profile obtained experimentally by Jonsson is analogous to that of the present theory.

On Transformation of Shallow Water Waves off the Ogata Coast

By Yuichi IWAGAKI, Tadao KAKINUMA and Takeshi MONJI

Proceedings of the 16th Conference on Coastal Engineering in Japan,
December, 1969, pp. 69-73 (in Japanese).

Abstract

Ten-minute simultaneous wave records have been obtained in shallow water off the Ogata Coast by six step-resistance type wave gauges set along a long pier at depths of 6～7 m and one step-resistance type wave gauge at a tower located at a depth of 25 m.

This paper presents the results of wave observations analyzed both by the significant wave method and by the wave spectrum method.

The main results obtained are as follows:

1) The relationship between bottom friction factors and wave Reynolds numbers in shallow water off five Japanese coasts obtained by Iwagaki-Kakinuma (1966) are relatively applicable at offshore-side stations.

2) The calculated values of bottom friction factors derived from observed data at onshore side stations are much greater than those off five Japanese coasts.

3) The bispectra, skewnesses, and kurtosises of waves are obtained at both the offshore and onshore side stations. As a result, it seems that the interactions between spectral component waves at onshore side stations differ from those at offshore side stations both in strength and behaviour.

4) Some significant wave heights at the onshore side station are greater than those at the offshore side station 54 m distant from the onshore side station when incident waves are comparatively high.

On a Tsunami Generator

By Yuichi IWAGAKI, Yoshito TSUCHIYA and Shigehisa NAKAMURA

Proceedings of the 16th Conference of Coastal Engineering in Japan,
December, 1969, pp. 353-358 (in Japanese).

Abstract

Tsunami problems have been studied by various researchers theoretically and experimentally. The research on tsunamis may be classified thus: 1) generation and propagation of tsunamis; 2) behaviour of tsunamis in harbours; and 3) analyses of tsunami records. Although various researches have been made, the results do not give complete and practical solutions for problems of tsunamis in coastal regions.

It is necessary to construct a dynamically simulated model and a well designed wave generator. The tsunami generator should be designed in view of model scale and boundary conditions. There have been devised several tsunami generators: 1) flutter type, 2) pneumatic type, and 3) hydraulic type.

The authors designed a tsunami generator which consisted of a hydraulic servo system and plunger. The hydraulic servo system controls the plunger automatically following a cam to produce an input function. The characteristics of the wave generator will be determined by not only the capacity of the hydraulic servo system but the scale of a harbour model.

If a plunger of area R moves dh in a time dt and the water level in front of the plunger changes $d\zeta$ within a basin whose area is S, assume that the water flow Q exists across a vertical section A from the part of S to the outside of S. Under this condition, the relation

$$R\,dh = S\,d\zeta + Q\,dt$$

will be hold as a first approximation of continuity. The value of Q should be given with the consideration of the equation of motion. Referring to the above relation, the water level is related to the displacement of the plunger which corresponds to the radius of the cam prepared.

On the Motions of Bed Load Sediments in Turbulent Streams and Their Mechanics

By Yoshito TSUCHIYA and Toshiki AOYAMA

Proceedings of the 14th Conference on Hydraulics, February 1970,
pp. 13-18 (in Japanese).

Abstract

It is necessary to describe the mechanics of sediment transport by running water in relation to the mechanics of transport of sand grains and snow particles by wind. In this paper, after some considerations on the forms of motion of bed load sediments, a theory on the saltation of sand grains is proposed with the aid of some assumptions for the rolling motion of a sand grain, the collision characteristics of a saltating sand grain with sand grains on the bed, and the equations of motion for the saltation.

In the first part of this paper, seven essential forms of motion in the motion of bed load sediments newly defined are described briefly in relation to the stochastic process from one form of motion to another, based on the results of experiments carried out with a 16 mm high speed camera and a film motion analyzer.

In the second part, four essential motions of sand grains, namely, rolling motion and its transition to saltation, the first saltation from the rolling motion, the collision mechanism of a saltating sand grain with sand grains on the bed, and successive saltation are considered theoretically. It was found that the theoretical results of studies of rolling motion are in good agreemant with those of studies of the rolling distance and velocity of a sand grain and the distribution characteristics. Theoretical study of the successive saltation of sand grains shows good agreement with observation data on the saltation height and distance of sand grains in stationary saltation and their distribution characteristics. Furthermore, some characteristics of the saltation of a cloud of sand grains are described on the basis of the above theoretical considerations.

A Study on Mass Transport in Boundary Layers in Standing Waves

By Hideaki NODA

Coastal Engineering in Japan, Vol. 12, March, 1970, pp. 57-68 (in English).

Abstract

This paper described in the Bulletin, Vol. 18, Part 5, August, 1969, into English, deals with mass transport in boundary layers developed on horizontal bottoms by standing waves in shallow water.

In a theoretical approach, the basic equations of laminar boundary layers are applied to solving the oscillatory motions on the boundary layers caused by standing waves. The mass transpors velocities are derived on the basis of solutions of the second approximation which describe the flow velocity near the bottom.

In addition, experimental measurements in standing waves of mass transport velocity in the boundary layers developed on smooth and rough bottoms were carried out using dye streak and solid particle methods.

The experimental data are compared with the theoretical prediction and the following conclusions are derived:

1) Mass transport observed in a laminar boundary layer conforms to the values predicted theoretically; and the direction of the mass transport in the upper layer is contrary to that in the lower one.

2) The mass transport velocities observed on a rough bottom are greater than those predicted by the laminar theory for a smooth bottom: but the direction of mass transport is in agreement with that given by the theoretical prediction.

A Microscopic Consideration of the Shearing Behavior of Granular Materials Using Two-dimensional Models

By Sakuro MURAYAMA and Hajime MATSUOKA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 505-523 (in Japanese).

Abstract

This is a report on a microscopic consideration of the shearing mechanism in granular materials such as sand and gravel. In order to investigate this mechanism through observing microscopically the interaction between particles, the direct shear test was carried out by using a horizontal pile of alminium rods with various diameters as a simulation of a two-dimensional granular mass. Another direct shear test was performed by using a similar horizontal pile of rods made of photoelastic material to measure the interparticle force transmitted during the shearing process.

Besides these tests, a simulation of a two-dimensional particle arrangement (structure) in the initial state before shearing was obtained analytically by applying Monte Carlo methods.

In these investigations, the interparticle force f, the frictional angle between particles δ, and the slope angle of the particle surface at the individual contact point against the general shearing plane θ were chosen as fundamental factors to control the shearing resistance of the materials. Among these, the frequency distribution of θ $(-90°<\theta<90°)$: $N_j(\theta_j)$ $(\theta_j-\Delta\theta/2<\theta_j<\theta_j+\Delta\theta/2)$ was adopted as a factor to evaluate the particle arrangement (structure) on the shearing plane during shear, and it was found that this factor dominated the stress ratio-strain-dilatancy character of the materials. It was also found that $N_j(\theta_j)$ was related to the sum of the interparticle force in the same small range $\Delta\theta$ of θ: $F_j(\theta_j)$ by the equation, $F_j=CN_j^2$ (C: const.), which was obtained from the photoelastic experiment of the pile of rods. From this relation $\tan\phi_{m0}(=\tau/\sigma_N)$ can be calculated by the following equation if $N_j(\theta_j)$ is known.

$$\tan\phi_{m0}=\frac{\tau}{\sigma_N}=\frac{\sum_{j=1}^{m}N_j^2\cdot\sin(\theta_j+\delta)}{\sum_{j=1}^{m}N_j^2\cdot\cos(\theta_j+\delta)}\quad(m:\text{ the number of the ranges of }\theta)$$

This calculated ϕ_{m0} agrees well with the measured ϕ_{m0}. Furthermore, some macroscopic mechanical properties obtained by repetitional loading tests were explained from a similar microscopic point of view.

Earth Pressure on Tunnel Lining Caused by Stress Relaxation of Cohesive Ground

By Sakuro MURAYAMA and Hajime MATSUOKA

Proceedings of the Japan Society of Civil Engineers,
No. 168, August, 1969, pp. 37-43 (in Japanese).

Abstract

It often happens that earth pressure on a tunnel lining built in cohesive ground increases with time. One of main causes of this phenomenon is supposed to lie in the stress relaxation of the cohesive ground around the tunnel. A characteristic equation for the earth pressure caused by such stress relaxation has been derived from the rheological property of cohesive soil in the visco-elastic state. In order to verify this theoretical equation of earth pressure, the results obtained from it are compared with those of experiments carried out by using a model tunnel driven into cohesive soil. One of the results obtained by the experiments is shown in Fig. 1. From this figure, it can be seen that earth pressure on the tunnel lining due to stress relaxation of the ground increases in proportion to the logarithm of time and it reaches a certain finite intensity asymptotically after a long time. This finite intensity of the earth pressure after a long time can be estimated from the theoretical equation.

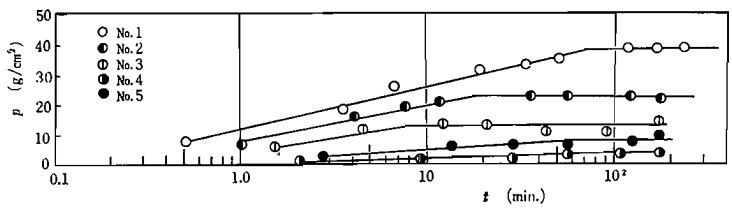

Fig. 1 Experimental data showing earth pressure p vs. time t.

An Example of Field Measurement of Earth Pressure Applied on Steel Tunnel Supports

By Sakuro MURAYAMA, Hidehiko NAKASAKI, Hajime MATSUOKA and Yasutaka MAEDA

Journal of the Japan Society of Civil Engineers, Vol. 54, No. 11, November, 1969, pp. 45-49 (in Japanese).

Abstract

The earth pressure acting on steel tunnel supports is usually estimated from the measurement of the top and bottom fiber strain. But it is very difficult to calculate this earth pressure exactly from strain measured only at the upper and lower flanges of a steel tunnel support (H-steel), because only two sectional forces (bending moment and axial force) can be calculated from this measured strain, and the third sectional force (shearing force) remains unknown. Murayama-Matsuoka (1968) proposed that the shearing force can be calculated from the strain measured by a Rossete gauge, which can measure strain in three directions; and that the earth pressure applied on a steel tunnel support can be exactly calculated from the bending moment, the axial force and the shearing force by setting up an equation of equilibrium.

The results of field measurements based on this new method of earth pressure determination are reported in this paper, and they are found to be more reliable and accurate from various points of view than measurements by the usual method.

On the Settlement of Granular Media Caused by Local Yielding in the Media

By Sakuro MURAYAMA and Hajime MATSUOKA

Proceedings of the Japan Society of Civil Engineers, No. 172,
December, 1969, pp. 31-41 (in Japanese).

Abstract

In order to investigate the settlement of granular media due to local yielding, such as the local failure caused around a tunnel excavation, a series of model tests was performed by using a horizontal pile of aluminium rods with various diameters for simulating a two-dimensional granular medium. In these tests, the settlement of the granular medium was caused by gradually lowering a panel which formed a part of the horizontal base under the pile of rods.

The theoretical equation of the settlement at the free surface and inside of a granular medium along the center line of the lowering panel has been derived from the following facts of the settlement behavior.

(1) The shape of the settlement zone can be determined on the base of the shape of "the primary zone", where the medium settles in the same way as the lowering panel. The width of the settlement zone b is expressed by the following equation.

$$\frac{b}{B}=C_1\cdot\frac{D}{B}+C_2$$

(B: width of the lowering panel; D: depth of the medium; C_1, C_2: material constants determined theoretically and experimentally)

(2) Lowering the panel causes not only the settlement of the free surface of the medium, but also increases the void ratio in the medium. This increase of void ratio has a critical value (critical void ratio) and occurs particularly in the two sliding zones between the settlement zone and the surrounding stable zone.

(3) From the experimental results of $\Delta\rho/\Delta\delta$ *vs.* δ(ρ: the settlement of the media; δ: the lowering amount of the panel), it can be assumed that ($\Delta\rho/\Delta\delta$) increases linearly with δ and reaches a certain constant value. This constant value can be calculated when no more void is produced in the arch-shaped system of the medium surrounded by a pointed arch and two inclined sliding planes.

Experimental values of the settlement agree well with the theoretical curves based on the equation. Furthermore we have checked experimentally that this theory developed for a pile of rods is valid for sand and gravel as media.

Study on Two-Variate Gamma Distribution and Its Engineering Application
— Fundamental Theory of Two-Variate Exponential Distribution —

By Masashi NAGAO and Mutsumi KADOYA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 105-133 (in Japanese).

Abstract

The object of this study is to develop fundamental theories of two-variate gamma and exponential distributions for engineering application. Recently, stochastic techniques such as regression analysis and data generation have played an important role in a system approach to the problems of flood control and water resources. In most cases, however, a technique based on normal distribution is used even though hydrological quantities do not follow normal distribution curve but a skewed one usually, because a technique based on a skewd distribution is not completely developed yet. This situation urged us to begin this study.

First, this study was carried out on two-variate gamma distribution, the probability density function of which is defined as follows:

$$f(x_1, x_2)=\frac{1}{\Gamma(\nu)(\sigma_1\sigma_2)^{\frac{\nu+1}{2}}(1-\rho)\rho^{\frac{\nu-1}{2}}}\exp\left\{-\frac{x_1}{\sigma_1(1-\rho)}-\frac{x_2}{\sigma_2(1-\rho)}\right\}(x_1x_2)^{\frac{\nu-1}{2}}I_{\nu-1}\left(\frac{2\sqrt{\rho}}{1-\rho}\sqrt{\frac{x_1x_2}{\sigma_1\sigma_2}}\right)$$

in which ν, σ_1 and σ_2 are parameters; ρ is the correlation parameter; $\Gamma(\nu)$ is the gamma function with an argument ν; and $I_{\nu-1}(z)$ means the modified Bessel function of the degree $\nu-1$. Methods of estimation of the parameters included in the above equation were developed using the technique of maximum likelihood and the method of moment. As for the results, it became clear that the estimator for the correlation parameter, ρ, by the latter is coincident with the ordinary Pearsonian definition of correlation coefficient, but the one by the former is not.

Next, the character of the two-variate exponential distribution, which is a special type of the gamma distribution, especially the character of a correlation surface and locus of the mode of the conditional probability density function were clarified theoretically and numerically in relation to the correlation parameters.

Finaly, numerical values of the conditional probability function defined as

$$F(\xi\,|\,\eta)=\int_0^{\xi}\frac{1}{1-\rho}\exp\left(-\frac{\xi+\rho\eta}{1-\rho}\right)I_0\left(\frac{2\sqrt{\rho}}{1-\rho}\sqrt{\xi\eta}\right)d\xi$$

in which $\xi=x_1/\sigma_1$ and $\eta=x_2/\sigma_2$,

were obtained to provide a table for the convenience of engineering applications of the two-variate exponential distribution. The table was prepared for $\xi=0.25(0.25)10(0.5)14(1)18$, $\eta=0(0.25)3.0(0.5)5(1)10(2)18$ and for $\rho=0.1(0.1)0.9$.

Application of Generated Daily Rainfall Sequence to Optimal Design of Drainage Pump Capacity

By Mutsumi KADOYA, Akira FUKUSHIMA and Toshio JYOTATSU

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 135-145 (in Japanese).

Abstract

A study was made of the possibility of representing a daily rainfall sequence by a simple stochastic model using a digital computer, and of the effectiveness of applying the data generated by this model to the optimal design of a drainage system.

First, some stochastic characteristics were examined of the historical data observed at the Kyoto Meteorological Observatory for the period 1936 to 1965. It was concluded; 1) that the probability distributions of continuous rain and no-rain days are almost the same with each other and that these may be regarded as exponential distributions; 2) that the distribution of daily rainfall depth seems to be of an exponential type but changes its shape in season to yield three types of period, which are summer (June-September), winter (December-March) and spring-autumn (April-May, October-November); 3) that the daily amount of evaporation may be treated as negative daily rainfall depth to simplify the model for a daily rainfall sequence; and 4) that the sequence in summer is to be regarded as a first-order autoregressive sequence and the others as independent sequences. The historical data were normalized to estimate the autoregressive coefficient more exactly than the one based on the raw data, and the first-order normal Markov model was used to generate the daily rainfall sequence in summer. There was no paticular problem in generating the sequence for the other periods. The generated sequences were good in the stochastic sense.

Next, hydrographs of water level in the inundation area of lower reaches of the Yamashina River were examined. We found that the hydrograph for a rain storm is affected by the initial water level just before the rain; that the hydrograph removed from the influence of this initial water level is classified generally by cumulative rainfall depth at every 6, 12, 24 and 48 hours from the beginning of the rain; and that the initial water level seems to fluctuate around a special water level marked to keep it constant corresponding to the growth stage of crops for irrigation in this area. Based on these results, the following technique was adopted to synthesize a hydrograph for a given rain storm: The rainfall depth of the first day of the rain storm is divided into the depths for 6 and 12 hours using random numbers of 0-1. The initial water level is determined using a random number of 0-1 and the cumulative probability density curve for initial water levels corresponding to the month in which the rain storm occurs.

Hydrographs for rainstorms were sythesized using daily rainfall sequence generated for a period of 100 years and the above mentioned technique. Annual benefits and drainage costs were calculated under some hypothetical pump capacities and a design criterion for an optimal drainage system was discussed.

Digital Simulation of Groundwater Flow in a Wide Alluvial Fan
— Studies on Groundwater in the Basin of the River Ta (3) —

By Taro OKA and Mutsumi KADOYA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 161-169 (in Japanese).

Abstract

This study examines the possibility of simulating the daily fluctuations of the groundwater table in a wide alluvial fan and the outflow from springs in the fan by a mathematical model using a digital computer.

The alluvial fan bounded by the Rivers Ane, Takatoki and Ta and mountains was selected as a research basin. The River Kusano, one of the tributaries of the River Ane, runs within the fan and plays an important role in the behaviour of the groundwater in the basin as an effluent stream; but it sometimes changes to a dry river in summer. There are some groups of springs at the end of the alluvial fan formed by the River Kusano. Irrigation water in this area depends upon surface water in the River Kusano, outflow from the springs, and water pumped up from aquifers. These situations complicate the behaviour of the groundwater in the basin.

The mathematical model for simulating the behaviour of groundwater is based on the fundamental equations obtained using the Dupuit assumption and the elastic theory for two dimensional transient flow in unconfined and confined aquifers respectively. In solving the fundamental equations, the following conditions were assumed: The groundwater table in a river is equal to the height of the bed of the river except for a dry river. The inflow of groundwater from mountains to the basin is neglegible. The River Kusano acts as an effluent river in the upper reaches with surface water, but as ordinary farm land in the lower reaches without surface water. The effects of withdraual of water from aquifers on the groundwater flow by a number of pumps with small capacity are almost the same as the effects produced by a hypothetical few pumps with large capacity. A pump acts continuously without stopping for the entire irrigation period except on days with over 10 mm of depth per day of rain. Based on these assumptions, numerical maps with a mesh interval of 200 m were prepared for giving boundary conditions at beginning of the calculation for irrigation and non-irrigation periods.

The fundamental equations were solved numerically using the technique of finite difference by a digital computer to simulate the groundwater table and the outflow from springs in the basin for the six months from February 1 to August 31, 1969. In this calculation, the time unit was taken as 4 hours and the aquifer constant was determined by trial because of lack of data. The results obtained were valid generally, except for a few problems due to inappropriate assumptions, such as that the inflow of groundwater from mountains would be neglegible, for example, and to uncertain factors such as the operation of the pumps.

A Study of the Seepage around Sheetpile, Applying Forchheimer's Law

By Taro OKA

Proceedings of the 13th Congress of the International Association for Hydraulic Research, Vol. 4, 1969, pp. 135-142 (in English).

A Study of Confined Seepage around Sheetpile, Applying Forchheimer's Law (2) — Seepage Problems for River Structure (2) —

By Taro OKA

Annuals, Disaster Prevention Research Institute, Kyoto University, No. 13B, March, 1970, pp. 147-159 (in Japanese).

Abstract

In these papers, some steady confined seepage problems in a region beyond the applicability of the Darcy law are discussed both theoretically and experimentally.

The experimental data on confined seepage flow around a sheetpile show that the relationship between total water head loss and seepage flux is not proportional and the solution of the Laplace equation derived from the Darcy law cannot sufficiently explain the experimental data.

In the first paper, a fundamental equation is derived using Forchheimer's law approximately, neglecting the normal velocity component to an axis in two dimensional orthogonal coordinate; then it is solved numerically to explain the experimental data using the technique of finite difference. The computer solutions of the equation agree pretty well with experimental data.

In the second paper, a fundamental equation is derived using Forchheimer's law strictly; then it is solved by the same technique of finite difference. The computer solutions of this equation are also good to explain the experimental results. But the difference between the solutions of the first and the second equations based on Forchheimer's law is insignificant in comparison with the experimental errors in spite of the rigorousness of the second equation. The equation derived from Forchheimer's law is useful for cases of confined seepage in a non-Darcy region. When the computer solutions of the second and Laplace equations for seepage flow under a low dam with sheetpiles are compared, the velocity distribution curve shown by the former in a high speed region becomes more gentle than the curve shown by the latter; the water head obtained by the former for a given discharge is greater than that obtained by the latter; but the difference between the two of the distribution of uplift pressure at the bottom of the dam is insignificant.

On the Flood Waves in a Prismatic Open Channel

By Tamotsu TAKAHASHI

Bulletin of the Disaster Prevention Research Institute, Kyoto University,
Vol. 19, Part 4, No. 164, March, 1970, pp. 21-39 (in English).

Abstract

The one-dimensional theory of unsteady flows in an open channel is based on the so-called Saint-Venant's equation. Since this equation is derived from the Navier-Stokes equation by omission of the vertical and horizontal accelerations, it cannot stand for all flow phenomena, even in a prismatic open channel.

This paper treats the unsteady flows in a prismatic open channel represented by the Saint-Venant equation through theoretical considerations and clarifies the limits of application of this equation, and then discusses flood characteristics in a laboratory test flume.

First, the author has shown that unsteady flows in a prismatic channel can be classified by an index $\lambda(\lambda \equiv (H_m - H_0)/i\sqrt{gH_m}\,T_D$, in which H_m and H_0 are the maximum and base flow depths respectively, T_D is the duration time of depth variation, i is the channel slope, and g is the acceleration of gravity). The critical value of λ, above which the waves break into the bore was obtained by the expansion of h and v in power series near the wave front, where h and v are non-dimensional quantities of depth and velocity respectively. Below the critical value, bore formation is prevented and in the case where the value of λi is the order of unity or larger the waves propagate as "dynamic", and Saint-Venant's equation must be modified for the effects of vertical acceleration, and if $\lambda i \ll 1$, the wave is "kinematic". The author has obtained the second approximation of the kinematic wave in cases where $\lambda \ll 1$ and $\lambda i \ll 1$ by the expansion of h and q in the power series of λ, where q is the non-dimensional quantity of discharge, and has compared the results with those obtained directly from a computer.

Second, flood characteristics, such as the variations of wave profile, propagation speed and stage-discharge relationship, are discussed in connection with theoretical considerations and experiments. The main results are: 1) that the flood often propagates like uniform translation waves at the rising stage as the results of the synthetic effects of the non-linear kinematic wave and the curvature of the wave profile; 2) that the peak propagation approximately obeys Kleitz-Seddon's law and the actual front propagates with about the same speed to the peak because the theoretical front which propagates with long wave celerity decays exponentially. But the larger the value of λ, the faster the propagation velocity of the front; 3) the peak attenuation with propagation approximately obeys the hitherto theories.

A Study of Suspended Sediment (1)
—Concentration of Suspended Sediment near the Bed Surface—

By Kazuo ASHIDA and Masanori MICHIUE

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 233-242 (in Japanese).

Abstract

In this research, the distribution of size frequency of suspended sediment and its concentration near the bed surface were investigated both experimentally and theoretically.

An equation to express the distribution of size frequency of suspended sediment was introduced, and it was found that it agreed with experimental data. It was also confirmed by the distribution of size frequency of suspended sediment that the equation proposed by Rouse which expresses the vertical distribution of the concentration of suspended uniform sediment can be adapted for the suspension of graded sediment.

Moreover, the motion of suspended particles in a turbulent flow is discussed on the basis of the equation of particle motion introduced by Tchen. The characteristics of unsteady motion in the first stage of a particle which is at rest at origin were especially calculated under certain assumptions. Using these characteristics of particle motion, a model for the expression of the concentration of suspended sediment near the bed surface was made and an equation for the estimation of the concentration near the bed surface was obtained. The experimental data showed that this equation can yield this concentration on the condition of maximum capacity of the transportation of the suspension in a turbulent flow.

Flood Flow in an Irregular Channel (1)

By Tamotsu TAKAHASHI

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 299-310 (in Japanese).

Abstract

Unsteady flows in irregular open channels which have considerably large storage regions abutting on the main channel are difficult to solve by the exact equations, even with a high speed digital computer, because of the complexity of the hydraulic characteristics. An approximate equation to express unsteady flow under this kind of channel condition has been derived through theoretical considerations on a one-dimensional system of equations of continuity and momentum. The newly derived equation, that is

$$\frac{\partial h}{\partial t}+\frac{B_m}{B_m+B_d}\cdot\frac{5}{3}u\frac{\partial h}{\partial x}=\frac{B_m}{B_m+B_d}\left\{\frac{hu}{2\left(i-\frac{\partial h}{\partial x}\right)}+D_L\right\}\frac{\partial^2 h}{\partial x^2},$$

where h, u and i are the depth, velocity and slope of the main channel region respectively, B_m and B_d are the widths of the main channel and storage region respectively, D_L is the coefficient of large scale horizontal mixing and t and x are time and distance respectively, is a modification of the terms for transportation and diffusion in the diffusional equation derived by S. Hayami.

The linearized equation of the above fundamental equation (under the assumption that the coefficients of differential terms in the fundamental equation are constant within comparatively small distances and times) reveals that the larger the width of the storage region and the value of D_L, the larger the attenuation of the flood becomes.

A comparison between routed flows using actual and averaged cross-sections after the numerical integration of the non-linear fundamental equation indicates that the solution obtained using widths averaged along the complete river reach is a good approximation for the irregular channel flood.

The application of this theory to the flood produced by Typhoon 5915 (Vera) in the Kizu River has shown good agreement with the observed hydrograph.

Weathering of Rock and Landslides (1)
—Weathering of Granitic Rocks—

By Katsumasa YANO and Toyoaki SAWADA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 621-627 (in Japanese).

Abstract

Preliminary research into the character of landslides in acidic intrusive rock, have already been described (Yano. etc.).

The present investigation examines the relation between weathering of rocks and landslide. The relation between the compressive strength and the density of joint net in these rocks helps to elucidate the practical order of weathering.

To determine the characteristics of weathering we measured the compressive strength, and the density of joint net, and analyzed the clay mineral in the rocks. The compressive strength was measured by 'Schmidt' test hammer. The density of joint net was measured in the field. The clay mineral observed in thin section, was analyzed by X-ray diffraction meter.

The order of weathering (capacity of landslide) was found to be decided by the expanse of compressive strength and density of joint net in the granitic rocks. The capacity of landslide in the rock was affected by the characteristics of the rock which were influenced by pre-weathering actions, namely, hydrothermal metamorphism and hypogene actions.

Distribution of Ground Waters in the Gamata River Basin —General Condition of Landslide and the Geochemical Characters of Ground Waters—

By Katsumasa YANO and Toyoaki SAWADA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 629-645 (in Japanese).

Abstract

Along the Gamata River Basin there exist numerous landslides. The character shape, distribution and development of these landslides is very dependent on their geology. Knowledge of geological conditions in the landslide area is important for understanding the mechanism of the occurrence of landslides in this basin.

To investigate the geochemical features of this area, the authors determined the distribution and the change with time in the chemical composition of ground waters. That is, from August 1968 to November 1968, ground water samples were taken at intervals of two weeks and their composition was determined.

Temperature, pH, and conductivity values were measured in the field; and chemical constituents such as Na^+, K^+, $Ca^{2+}+Mg^{2+}$ and soluble SiO_2 were determined in the laboratory.

General tendencies were as follows:

(1) The concentrations of soluble SiO_2 increased after a period of rain.

(2) The concentrations of $Ca^{2+}+Mg^{2+}$ decreased after a rainy period.

(3) A reverse relation of concentration was observed between the soluble SiO_2 and the $Ca^{2+}+Mg^{2+}$.

(4) The variation of the concentrations of $Ca^{2+}+Mg^{2+}$ and soluble SiO_2 after a rainy period were large in the landslide areas.

Forecasting of Atmospherie Stagnation in the Kyoto Basin

By Chotaro NAKAJIMA

Bulletin of the Disaster Prevention Research Institute, Kyoto University,
Vol. 19, Part 3, No. 163, February 1970, pp. 39-53 (in English).

Abstract

The Kyoto Basin is surrounded on three sides by mountains about 300–500 m high. So, in winter, temperature inversion is apt to develop in this basin. Sea breezes do not come directly from the sea. In Kyoto, there are not large factories; however the concentration of air pollution increases as much as that of a big industrial city, especially on winter mornings. We observed the temperature distribution in the vertical north-south cross-section in the Kyoto Basin using thermister thermometer recorder mounted on a small plane. After analysing the vertical distributions of temperature and wind, we find that the difference between minimum temperatures on the top of Mt. Hiei and at the bed of the Kyoto Basin is a good indicater of the degree of air pollution in Kyoto Basin.

The final purpose of forecasting air pollution is to prevent it. For actual work to prevent air pollution, several or 10 days forecasting is hoped for. For the preparation of such prolonged forecasting, we examined the variations of the concentration of pollutants, the index of stability described above, and the height of the 500 mb surface over Kyoto for winter days over two years. Finally, 4-days mean 500 mb height patterns over the Far East were drawn. We found a high correlation between these elements especially in mid-winter. In mid winter, generally, the negative deviation area over Japan indicates the strong wind winter type (corresponding to weak air pollution), and the positive deviation area over Japan indicates the warm winter type (corresponding to strong air pollution). We can forecast the future mean 500 mb height patterns by the usual synoptic method. With these facts, we discuss the possibility of forecasting atmospheric stagnation in the Kyoto Basin.

Studies on Heavy Rainfall (II)

By Chotaro NAKAJIMA and Yukio GOCHO

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 17-32 (in Japanese).

Abstract

The frequency distributions of heavy rainfalls (200 mm/day or more and 300 mm/day or more) for ten years (1956-1965) over the whole of Japan were shown. The highest frequencies of heavy rainfalls above 200 mm/day and 300 mm/day were about 3 days/year and 1.5 days/year respectively. The areas with these high frequencies lay along the south coast of Japan corresponding to areas of large precipitation. In all areas with the highest frequencies there were mountains higher than about 1000 m. The areas with relatively high frequencies were found in the regions near the northern ends of straits and bays opening to the south. The areas with relatively high frequencies in Eastern Japan, thougn they were considerably narrow, were around Mt. Tateyama in the north of the Hida Mountains and around Nikko in the northern Kanto district. It seems that the frequency distributions of heavy rainfalls reflect topographic influences clearly.

The relation between the 500 mb height pattern in the Far East and location of heavy rainfalls (200 mm/day or more) for ten years over the whole of Japan was investigated. 500 mb height patterns were divided into three main types as follows: (A) the case in which the trough and ridge of the long wave indicated in the 500 mb height pattern were located in the east and the west of Japan respectively and north-west wind prevailled over Japan, (B) the case in which the large trough was located over Japan and west wind prevailed, and (C) the case in which the trough and ridge were located in the west and east of Japan respectively and south or south-west wind prevailed. Moreover, types B and C were subdivided according to the location of the axis of the jet stream of the 500 mb level. Thus the height patterns were classified into nine types in all, each of them represented the characteristic distribution of the heavy rainfall areas. This is important from the standpoint of weather forecasting.

Basic Study on Salt Damage (IV)
Distribution of Sea-Salt Particles near the Coast

By Masaaki TANAKA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 445-456 (in Japanese).

Abstract

The results of the observation of the distribution of giant sea-salt particles near the coast were described, and the impaction-sedimentation ratio, γ, which has great significance in the problem of salt damage, was estimated from the observed horizontal distribution of the particles.

The observations of the horizontal distribution of the salt mass and the number concentrations of giant sea-salt particles near the ground were carried out at 6 stations spread out from the coast inland near Ogata, Niigata Prefecture, along the direction of the winter monsoon, on Dec. 6 through 8, 1968. At the same time the vertical distributions of the winds were observed at the Ogata Wave Observatory. The observations of the horizontal distribution of the number concentrations were made twice a day, in the morning and in the afternoon. These observations showed that the particle number concentration and salt mass at the coast increased with the speed of winds from the sea, the particle number concentration and salt mass near the ground decreased with distance from the coast and their values at 40 km from the coast was one order smaller than those at the coast. The wind direction and speed changed day by day. On Dec. 6, 7, however, the prevailing wind direction was from north to west from the sea and wind speed from the sea near the surface up to the 1000 m level ranged from 2 m/sec to 6 m/sec over this area, so that the sea-salt particles over this area were considered to be transported from the Japan Sea.

The meteorological conditions on Dec. 6, 7, were considered suitable for the application of our theoretical model of the transport of sea-salt particles to the analysis of the data. In order to estimate the impaction-sedimentation ratio, γ, the ratios of the number concentrations inland to the concentration at the coast were read out from the observed horizontal distribution and were applied to the dimensionless characteristic values which appeared in our theoretical model. The impaction-sedimentation ratio, γ, obtained from this observation was about 20 for 6 m/sec in wind speed, about 10 for 4 m/sec and about 4 for 2m/sec. The value of γ for 6 m/sec is in good agreement with that estimated in which previous report from an observation of the three-dimensional distribution.

On the Hydraulic Model Experiment on the Diffusion Due to the Tidal Current (IV)

By Haruo HIGUCHI and Takashige SUGIMOTO

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 457-470 (in Japanese).

Abstract

The similarities between the prototype and the hydraulic model in the horizontal diffusion phenomena due to tidal currents in broad and shallow tidal estuaries or coastal sea waters are studied. The gravitational force and turbulent shear stress at the bottom are taken as the external forces, but the effect of density, wind, and waves, which may influence the diffusion, are not considered. In the model, the Froude number is about 0.1, and the Reynolds number is the order of 4×10 where the depth is taken as the representative length.

The results obtained from model were as follows:

(1) tide, flow pattern and tidal locus in the area, including near river mouths and near harbors, are well reproduced.

(2) The diffusion coefficient obtained from the dye diffusion experiment (for instantaneous point source and continuous point source), that obtained from the dispersion of floats, and that obtained from the horizontal distribution of concentration of river water are all fairly expressed by the line of $K=0.02\sim0.04\,l^{4/3}$, for l from 100 m to 10 Km. The usefulness of the model experiment and its limits are discussed.

That is to say that:

(1) in the hydraulic model experiment, the movements of water masses near the mouths of the rivers and harbors, the horizontal mixing due to the current, and the distributions of the concentrations are well reproduced, but

(2) The distributions of concentrations are not correctly reproduced after long period since sink and flux at the model limit are not included in the model. They reach a quasi-steady state step by step from the discharge points; and if the model limit is taken at a distance of more than twice of the tidal locus from the discharge points, the quasi-steady state will attain in the first affected region, the one now in consideration, after 30 tidal cycles or so,

(3) when the water is shallow, the model must be exaggerated vertically to exclude the effect of the bottom viscous layer and surface tension. But such model distortion will introduce another effect into the diffusion coefficient and cause further problems of its own.

(4) The model can be used for the diffusion phenomena for the scale smaller than that the Corioli's force is effective and larger than that the molecular viscosity is effective.

Shear Strength of Sand under a Vibrating Load

By Toru SHIBATA and Hiroshi YUKITOMO

Bulletin of the Disaster Prevention Research Institute, Kyoto University,
Vol. 19, Part 3, No. 162, February, 1970, pp. 27-37 (in English).

Abstract

This paper presents some results of tests on the strength of saturated and dry sands under drained triaxial vibratory loading conditions. In these tests the loadings were controlled so that the values of τ_d/σ_N' were in accord with the angle of mobilized internal friction, ϕ_{m0}', where τ_d is the dynamic shearing stress on the shear plane and σ_N' is the dynamic normal stress.

The triaxial vibrating tests were carried out under the following loading conditions: the amplitudes of lateral confining pressures were kept constant at 0.1, 0.2, 0.3, and 1.0 kg/cm^2; and the amplitude of axial pressure was controlled so that the angle between the normal stress and the resultant vibrating stress was in accord with ϕ_{m0}'.

The comparisons between the test results on saturated sands under drained triaxial vibratory loading conditions and those of static triaxial compression tests are made. The dynamic strength of sands depends on various factors, and the tentative conclusions obtained are as follows:

(1) The angle of internal friction of sand ϕ' decreased with the increasing of σ_{3d}, the amplitude of lateral confining pressure. This tendency to strength-loss was observed to be almost the same irrespective of surface energy corrections. The observed accelerations of vibration at the upper end of the specimen were of the order of 10^{-2}g, and the effect of this on the strength of the sand did not seem to be remarkable. Nevertheless the ϕ'-values during vibration at $\sigma_{3d}=1.0$ kg/cm^2, for example, decreased about 6–8 degrees from the static ones. Moreover, the influence of the frequency of vibration on the strength of the sand was noticeable; the higher the frequency became the lower the strength was.

(2) In general, dynamic strength increases with the increasing of the density of sand, but this densification-effect of sand on the strength may not be expected for the larger external dynamic force. For example, in the case of a large amplitude of confining pressure, $\sigma_{3d}=1.0$ kg/cm^2, no difference of strength for the different initial void ratio was observed. One of the causes of this phenomenon may be the difference of the amount of volume change with the initial density of the sand.

Dynamic Pore Water Pressure in Saturated Sand

By Kenzo TOKI and Yoshio ISHIGURO

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 553-562 (in Japanese).

Abstract

One of the dynamic problems in soil mechanics is that of liquefaction in saturated sand. The mechanism of liquefaction in sand has been explained as follows: that the skeleton of the sand is broken down successively by the effect of dilatancy when saturated sand is subjected to vibration, if drainage is not possible. The tendency of decrease in volume produces an increase in pore water pressure and the effective stress tends to become zero, the sand loses its strength completely, and then goes into a liquefied state. Now it may be supposed that the dynamic pore water pressure which is always generated in saturated sand subjected to vibration affects intergranular stress.

In this investigation, the authors evaluated quantitatively the pore water pressure which is generated in saturated sand under a vibrating load. The dynamic water pressure in liquefied sand was measured at several observation points in a tank which was excited by a vibration table. The data obtained agree with those of analytical solution in which the liquefied sand was treated as water having the density of the submerged weight of sand.

Moreover, the effect of weight fluctuation on the liquefaction of saturated sand during earthquakes has also been discussed. This weight fluctuation is proportional to the vertical gradient of dynamic pore water pressure. Therefore the weight fluctuation is most notable at the surface of the saturated sand in a tank with regard to the vertical direction and at the boundaries with regard to the horizontal direction. If the weight fluctuation is closely related to the growth of liquefaction in saturated sand, it may be said that the liquefaction is much excited where the weight fluctuation is greater. Experimental data as to the horizontal direction are not given; we must leave this for future study.

Nonstationary Response of Underground Structures Subjected to Random Excitations

By Hisao GOTO, Kenzo TOKI and Takashi AKIYOSHI

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 579-592 (in Japanese).

Abstract

In seismic response analyses, it is important to take into account the dynamic effect of the surface layer around the foundation structures. The surface layer is in general a stratum over a solid half space, so that it forms a part of the kinetic energy of the structure not only be dissipated due to the viscous damping but also to be dispersed by radiation, when subjected to excitation. Some recent studies on frequency response analyses of underground structures show that the radiation of waves causes much damping effect to the structures, dependent on frequency.

When underground structures are excited by random disturbances, the analytic representation of the response at any given instant is usually given in the form of the convolution integral by making use of the unit impulse response function of the structures. In this paper some simplifications were made in the transmission dynamics of waves in obtaining the unit impulse response function of an elliptic rigid cylinder in elastic ground, because of the complexity of the frequency response. The process is that the dynamic effects of the surface layer on the structures, and the effects of spring action and of earth pressure, were represented by the approximate forms of frequency response, and their inverse transformations were obtained by some transformation of variables. The input excitation was considered as a nonstationary random process which was constructed as the product of a deterministic function and a stationary random process.

From the numerical computations, considerations were made for r. m. s. responses, correlation coefficients, rate of threshold crossings of a level per unit time and expected number of threshold crossings of a level. When the dominant period of input acceleration coincides with the natural period of the surface layer, the peak of r. m. s. response of the structure appears later than that of the input r. m. s. and this tendency is more remarkable in the vibration in the direction of the minor axis of the elliptic cross section than in that of the major axis. When one period, on the other hand, goes away from the other, both peaks of r. m. s. approach each other. The rate of threshold crossing per unit time of displacement response for a given level is larger for the vibration in the direction of the minor axis than for that in the direction of the major axis, as in the r. m. s. responses of displacement and velocity. The expected number of threshold crossings is generally larger for the vibration along the minor axis than for that along the major axis.

Elastic Wave Velocities in Sandy Soil

By Toru SHIBATA, Kenzo TOKI and Kunio TERADA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13B, March, 1970, pp. 593-609 (in Japanese).

Abstract

The propagation velocities of waves in soils or ground depend not only on the elastic modulus and specific weight, such as the homogeneous isotropic elastic continuum, but also on the porosity, moisture, stress, and strain level. As to the dependence of wave velocity on these factors, there may be two different currents of theoretical treatment. The first one is the theory of wave velocity in packed spheres, which discusses the dependence of wave velocities on stress level. The second is the theory of porous media. The latter one is concerning mainly with the coupling phenomena between the skeleton and the fluid when the four elastic constants and the porosity are given. As soils and/or ground may change their elastic modulus according to changes of porosity of the same material, it is of interest to us to represent the elastic modulus as a function of the porosity.

In this study both theoretical analysis and experimental investigation have been employed. By theoretical analysis a model which represents the dependence of the elastic wave velocity on porosity is derived for a liquid-saturated porous solid under the assumptions that the skeleton does not couple with fluid, and that the stress distribution in the skeleton and fluid is proportional to the occupied area in the unit area.

Laboratory tests, using the ultra-sonic pulse method which is familiar in rock mechanics, are carried out to measure the elastic wave volocity in specimens of three kinds of sand. The dependence of the wave velocity on the stress level as well as on the porosity is investigated. The results indicate that the elastic constants of the specimens are proportional to approximately the 1/2 power of the confining pressure and that they decrease for increasing porosity under the given confining pressures. From these findings the wave velocity of sandy soils is expressed, the theoretical analysis, as a function of: the maximum porosity, the density of particles, the bulk modulus of water, and the elastic constants of sand for the minimum porosity.

Moreover, on the basis of the field data a useful formulation on the relationship between the N-value and the propagation velocity of S-waves in sandy ground has been proposed using the similarity of the relationship between N-value and porosity to the relationship between the propagation velocity of S-waves and porosity.

Structural Response to Nonstationary Random Excitation

By Hisao GOTO and Kenzo TOKI

Proceedings of the Fourth World Conference on Earthquake Engineering,
Vol. I, pp. 130-144 (in English).

Abstract

There are two different approaches to the design of structures for seismic loading. The first one consists of the investigation of the response of structures to earthquake records; and the second is based on the probability method. However the strong-motion earthquake records obtained in the past are known to have statistical properties, and it is doubtful whether earthquake records taken on certain types of ground are applicable as an excitation for the analysis of structures on ground with different conditions.

Because of the statistical nature of earthquake records, the information which is obtained from the structural response to a single strong-motion earthquake is limited and then the earthquake motion is considered as stochastic processes. However, because the spectral composition of earthquake motions is affected by the frequency characteristics of their observation sites, simulation in which the frequency characteristics of ground are taken into consideration would be desirable.

In this study, earthquake acceleration is represented as a nonstationary random process which is described as a product of a nonstationary deterministic function and a stationary random process which has an arbitrary power spectrum. For this excitation, the structural response is very simplified and is represented by the response to the deterministic function. The root mean square values of the responses are calculated analytically; and by the use of this representation a method of generation of artificial earthquakes based on the Monte-Carlo method is presented.

The response of a structure to nonstationary random excitation is treated as a problem of threshold crossing; and the expected number of excess responses above certain levels is calculated as a function of the natural period of the structures with a single degree of freedom. With the aid of numerical computation a response spectrum which contains a probabilistic quantity as a parameter is presented. This spectrum gives information not only on the maximum value of responses but also on the value safety or risk. By using this response spectrum information is also provided on the effect of spectral characteristics and nonstationarity of earthquake motion.

Negative Skin Friction Acting on Steel Pipe Piles in Clay

By Toru SHIBATA, Masaaki ENDO, Arinobu MINOU
and Takato KAWASAKI

Proc. 7th International Conf. Soil Mechanics and Found. Eng.,
Vol. 2, August., 1969, pp. 85-92 (in English).

Abstract

Measurement of skin friction on four kinds of steel pipe piles was carried out for more than two years at a thick alluvial stratum where consolidation of 8 cm per year had been observed due to a decrease in pore water pressure in an underlying sand stratum. Several factors which influence negative skin friction, i.e., elapsed time, position of the neutral point, magnitude of skin friction, and load carried to the bottom end of the pile are discussed for the following cases: friction and point bearing piles, open point and closed point pipe piles, and vertical and battered piles. A method of estimating the magnitude of negative skin friction is discussed and proposed. The conclusions obtained are as follows:

(1) Except in special cases, a neutral point exists where the axial stress in a pile is maximum. The axial force due to negative skin friction is transmitted to the pile point while it is being diminished by positive skin friction acting on the pile below the neutral point. The observed ratio of the depth to the neutral point to the length of each pile in compressible strata fell within a range between 0.73 to 0.78, regardless of the variation in the manner in which the pile point was supported.

(2) The total negative friction on the closed point piles could be estimated fairly accurately by using $q_u/2$ as the average skin friction. In view of the physical nature of the negative skin friction, however, an expression in terms of the effective stress is considered more appropriate than $q_u/2$. In the case of open point piles, on the other hand, the total negative friction was approximately 60% of that for the closed point piles.

(3) Concerning the relationship between the negative friction and the relative displacement velocity of piles and soil, a considerable length of time was required before the negative friction was fully developed where the velocity was small. The negative friction showed no tendency to decrease with a decrease in the relative displacement velocity.

Creep Rate and Creep Strength of Clays

By Toru SHIBATA and Daizo KARUBE

Proc. 7th International Conf. Soil Mechanics and Found. Eng.,
Vol. 1, August, 1969, pp. 361-367 (in English).

Abstract

New data on the creep rate of clays are presented in the first section of this paper. A series of special drained creep tests, during which the water content was maintained practically constant, were performed on normally consolidated and over-consolidated clay samples having the same initial water content. An attempt was made to correlate both the shear and the normal effective stresses with the rate of creep strain.

In the second section, time-dependent changes in the strength of clays are described. Data on the creep strength or yield value obtained by the long-term drained and undrained creep strength tests are presented. These data are analysed on the basis of effective stress concept, and the flexibility of the yield value of clays in terms of effective stress is studied. The following tentative conclusions can be drawn from the tests performed during this investigation:

(1) The contours of equal creep strain rates plotted on the constant water content plane show that the creep strain rate $\dot{\varepsilon}_d$ essentially depends on the magnitude of shear stress τ irrespective of the effective normal stress σ' for appreciably smaller shear stress than the normal compressive strength, and that $\dot{\varepsilon}_d$ depends on the τ/σ' value for larger shear stress close to the normal compressive strength.

(2) The linear relationships between the logarithm of the creep strain rate and the deviator stress are found for both normally consolidated and over-consolidated clays, all tested under conditions of approximately constant effective stress and constant water content. The larger value of the stress factor, which is derived from the rate process theory and which provides a basis for obtaining a measure of the volume of the flow unit, is found for clay having larger over-consolidation ratio.

(3) Approximately the same value of ϕ' is obtained for the following three types of strengths: undrained creep strength in terms of effective stress, drained creep strength, and the normal compressive strength defined as the maximum effective principal stress ratio. This means that the rheological component suggested by Hvorslev may be negligible for a test duration lasting only a few weeks.

Effects of the Variation in Column Axial Forces on the Restoring-Force Characteristics of a Frame

By Minoru WAKABAYASHI and Taijiro NONAKA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 323-328 (in Japanese).

Abstract

An analytical study is made of the effects of axial force variation on the inelastic horizontal restoring-force characteristics of a rectangular frame. The example considered is a portal frame which is composed of two identical columns and a rigid beam, and which is subjected to a constant vertical load and to a varying horizontal force. The relation between the horizontal force and the displacement is sought when the latter increases monotonously. Large elastic-plastic deformation causes the interaction of plastic collapse and the instability which is due to change in geometry. The beam shear increases the compressive axial force in one column and decreases it in the other, so that the axial force variation gives rise to the addition of folds in the horizontal force-displacement diagram.

In the case of a small vertical load, an initially compressive axial force even becomes tensile in the course of horizontal force application. If the axial force remains compressive in both columns, the axial force variation little influences the frame behavior after the frame reduces to a mechanism with a sufficient number of plastic hinges. If one of the column axial forces changes the sign, however, the axial force variation reduces the maximum horizontal force the frame can carry. It is found, among other things, that the importance of axial force variation depends on the ratio of the column depth to the span. This effect can be neglected when the ratio is sufficiently smaller than unity.

The inclusion of the axial force variation makes the force-displacement diagram somewhat smooth, and to this effect may be attributed partially the fact that the experimental force-displacement diagram is much smoother than any available theoretical predictions.

Elastic Plastic Behavior of Full Scale Steel Frames

By Minoru WAKABAYASHI, Chiaki MATSUI, Koichi MINAMI
and Isao MITANI

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 329-363 (in Japanese).

Abstract

Previous experimental and theoretical studies on the aseismic design of frames have made clear that the instable effect due to column axial load and lateral displacement cannot be neglected in the lower storeys of a tall frame subjected to horizontal forces. However, these experimental studies were limited to miniature or medium-sized model tests, because of the difficulty of the simultaneous application of the horizontal and vertical loads. Though miniature model tests are utilized for studies on frame behavior, full-scale model tests are necessary for any final conclusions because of scale effects.

In this report the specimens were five unbraced and four braced portal frames with H-shape sections. The span of the frames was 5.0 m and the height was 2.6 m. The constant vertical load was 0 or 50% of the yield load of a column, and was applied to the top of the column. A monotonous or repeated horizontal force was applied to the connection of a beam and column. The elastic-plastic frame analysis was carried out under the following repeated moment curvature relations using a numerical integration method. 1) The moment curvature relation of the section under an axial force was of the bi-linear type in which the elastic zone increases to the maximum value of the previous cycle. 2) That of the section under no axial force was of the bi-linear type with no increasing elastic zone.

Overall behavior of the braced frames was obtained by superposing the horizontal force of the bracing members and that of an unbraced frame at the same displacement.

It was shown that the behavior of the frames was fairly well predicted by this analysis. Experimental and analytical results show that unbraced frames under no vertical load and hysteresis loops were of the closed mashing type, those under constant vertical loads behaved unstably, and hysteresis loops were of the unclosed negative bi-linear type. Braced frames under large vertical loads showed only slight unstable phenomena and hysteresis loops became the slip type.

Studies on Lateral Buckling of Wide Flange Beams, Report No. 1

By Minoru WAKABAYASHI, Takeshi NAKAMURA
and Haruki YAMAMOTO

Proceedings, Annual Meeting of the Architectural Institute of Japan,
August, 1969, pp. 1031-1032 (in Japanese).
Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 365-380 (in Japanese).

Abstract

Various problems concerning the lateral buckling behavior of wide flange beams remain to be studied; they are lateral buckling strength, post-buckling behavior, reasonable lateral bracing spacing, functions adequate for lateral bracings, and the effects of bending moment distribution on them.

Lateral buckling tests of wide flange beams were performed in the inelastic range of material. Test specimens were made of H-200×100×5.5×8 of SS 41 steel. All specimens consisted of three spans. The mid-span was to be observed and the side spans were to be loaded. Load was applied vertically at the ends of the side spans by oil-jacks. At the loading points and supporting points, the specimens were laterally braced and were able to rotate in the vertical and horizontal planes without constraint. The length of the side spans was 100 cm. Twelve specimens were tested having a linear moment gradient in the testing span with four testing span lengths (100, 150, 200 and 300 cm) and three end-moment ratios (+1, 0 and −1) as parameters. As a result of the tests, it was confirmed that the rotation capacity at a plastic hinge became larger as the bracing spacing was shorter, and as the moment gradient was larger. The test results in the case of uniform moment (+1 Series) agreed, with reasonable accuracy, with the formulae given by M. G. Lay for the relationship between the rotation capacity and the bracing spacing. The flange rotation after lateral buckling was smaller in the compression side, where the lateral displacement dominated, than in the tension side. Furthermore, the lateral displacement of the tension flange was very small. The lateral force exerted by the bracings was about 1.6% of the limit force of one flange in pure compression at the time of lateral buckling, and the lateral force was measured up to about 4.1% at maximum. The average value of the reactive twisting moment of specimens measured at the lateral bracings was about 4.4 t·cm at the instant of lateral buckling and about 12.6 t·cm at maximum.

A Model Test of a Prestressed Suspended Roof

By Minoru WAKABAYASHI, Tatsuo MUROTA, Koichi MINAMI,
Michio SHIBATA and Tsutomu TANAKA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 381-410 (in Japanese).

Abstract

For the large roofs of the sub-gates of EXPO '70, a prestressed suspended roof was adopted. On this occasion, two types of model tests were planned and conducted in order to get information for the design of such a structure.

Two 1/100-scale models were tested in a wind tunnel. A plastic model test was carried out to find the distribution of wind pressure coefficients. Test results showed that suction force dominates in most parts of the roof surface except in some small portions along the windward edges, and that there exists large concentrated wind pressure at the saddle-shaped surface, at the edged surface along the main cables, and near the column tops.

Another model was made of a thin rubber membrane to find qualitatively the dynamic characteristics of the roof surface. It was found that the vibration amplitude is proportional to the wind pressure and that the ratio of the amplitude to the static displacement is independent of the wind velocity.

Also, a cable model, which had a scale of 1/15, was tested statically. As main cables 4.2 mm-radius cables were used, and 1.54 mm-radius cables were used as subcables, whose ends were socketed by synthetic resin to supports, columns or main cables. Nonuniform loads according to the wind pressure distribution obtained from the wind tunnel tests, and uniformly distributed loads were applied to the cable model by means of weights for a total of 9 cases. Cable tensions were measured by tension-meters specially manufactured for this purpose.

Various data were obtained for each case to determine the initial prestressing-force distribution, the change in cable tensions, and the deflection of the roofs.

Theoretical assessment was also made on the above-mentioned structures under uniformly distributed loading, making use of step-by-step calculations of linear formulae of truss theory with cable pretension taken into account. This approach well predicted the nonlinear behavior of the structures, and showed a reasonable agreement with the test results.

An Experimental Study on Elasto-Plastic Characteristics of Composite Members Using an Encased H-Section Subjected to Combined Bending and Axial Force

By Minoru WAKABAYASHI, Koichi MINAMI and Katsuhiro KOMURA

Proceedings, Annual Meeting of the Architectural Institute of Japan,
August, 1969, pp. 861-862 (in Japanese).

Abstract

With the practical demand for very high buildings, the problems of stability and rigidity of such structures in the elastoplastic range of the material have increased in importance. So, a fundamental investigation was planned and made both experimentally and theoretically to obtain information on moment-curvature relationships of composite members under combined bending moment and constant axial force.

The experiments were carried out on four test specimens. The cross section (21cm × 21cm) adopted for the specimens was composed of an encased H-section with nominal reinforcement. The constant axial forces applied to these specimens were 0, 20, 40 and 60% of the yield load of the cross section. The bending moment was applied monotonously to the test specimen.

For the theoretical analysis, the moment-curvature-axial force (M-Φ-N) curves were derived from the geometrical relationships of the member cross sections and the stress-strain relationships of the materials, steel and concrete. Full composite action throughout the member was assumed. Also, a parabola was assumed for the elasto-plastic range of the concrete stress-strain curve, and a straight line was assumed for the plastic range. The tensile strength of the concrete was neglected. For steel, a bilinear stress-strain relationship was used. By a numerical calculation, M-Φ-N curves were obtained.

Both experimental and theoretical results are presented in this paper and compared for the values of the ultimate strength and the corresponding curvature. The comparison shows that the errors between the experimental and theoretical results are about 10% and 8%, respectively, for the values of the ultimate strength and the corresponding curvature. Thus, M-Φ-N curves obtained for the composite members studied turned out to be in good agreement with the experimental results.

Steel H-Columns under Biaxially Eccentric Load

By Minoru WAKABAYASHI, Taijiro NONAKA, Haruhito OKAMOTO
and Kazuhiko ISHIMARU

Proceedings, Annual Meeting of the Architectural Institute of Japan,
September, 1969, pp. 1063-1064 (in Japanese).

Abstract

In the case that multi-story steel frames are subjected to horizontal loads such as seismic forces and wind pressure, the columns of the lower parts are under biaxial bending and twisting as well as large axial compression. The behavior of such columns is so complicated that few investigations have been done.

This paper presents an experimental study and a theoretical one on the behavior and the strength of steel H-columns subjected to a biaxially eccentric thrust. In order to investigate the effect of the member length and the direction of eccentricity on the behavior and the strength of these shapes, experiments were carried out on 15 specimens with 5 different lengths and 3 different directions of eccentricity as parameters. Typical features of flexural-torsional buckling were clearly obseved in the series of tests of eccentric thrust on the web, whereas in all the other series of tests, flexural buckling dominated.

A theoretical analysis extended Ježek's approximate method for the case of eccentric uni-axial thrust to the eccentric biaxial case, taking into account the influence of the addi tional deflection of the member in the inelastic range, which assumes a half-sine wave for the torsional angle distribution as well as the deflection along the member. As for critical strength, the results were compared with those based on linear elasticity which neglects the effect of such additional deflection.

The theoretical analysis presented here turned out to give a fairly good estimate of both the critical strength and the behavior of these columns.

On the Effect of Axial Forces on the Plastic Collapse Load of Frames

By Minoru WAKABAYASHI and Taijiro NONAKA

Proceedings, Annual Meeting of the Architectural Institute of Japan,
August, 1969, pp. 1207-1208 (in Japanese).

Abstract

When applied to structural frames, the simple plastic theory of limit analysis ignores the axial forces existing in the members. It is well understood, however, that the member axial forces become large in some cases and that the existence of these axial forces much reduces the plastic collapse load. The usual approach to take care of this effect is an iterative method, in which one first determines axial forces on the basis of an approximate bending moment distribution obtained by neglecting this effect, and then one considers the decrease of fully plastic moments with reference to the axial forces. This approach may sometimes require several cycles of the iterative procedure in order to gain sufficient accuracy.

The present paper presents an analytical method for the determination of plastic collapse loads. This method takes account of the axial forces without resorting to an iterative procedure. This is a kinematical approach and is applicable to a general frame structure when the collapse mechanism is known. This method relies only on the flow rule and the geometrical constraints. Piecewise linearity of the yield condition is assumed for the combined action of bending moment and axial force. Changes in geometry and work-hardening property are assumed to be neglegible as in the definition of the plastic collapse load.

The method is applied to several examples of uniform rectangular frames. It is found that the effect of axial forces depends on two basic dimensionless parameters: the ratio of the column depth to the span, and the ratio of the beam depth to the column height. The effect becomes greater as these ratios get greater, and is neglegible, in general, when these ratios are sufficiently smaller than unity. In the example of a single-span ten-story frame with sandwich section, the inclusion of axial forces reduces the theoretical collapse load to one-third of that predicted by the simple plastic theory, when the frame is subjected to a horizontal load on top.

A Study of Stiffening a Column by a Lateral Support

By Yoshitsura YOKOO and Minoru WAKABAYASHI

Yawata Technical Report, No. 265, December, 1968, pp. 41-63 (in English).

Abstract

It is often required to provide an intermediate support for a compressive strut, in order to increase its buckling strength. A provision of the AIJ Code states that the support should be designed in such a way that it sustains the reaction of at least one per cent of the column load, but this requirement is not based on any reliable investigation. A study is made here on the validity of this design method by investigating the carrying capacity of an initially crooked column which is simply supported at both ends and elastically supported at the midheight.

It is considered here that an intermediate-supported column can bear the load which produces yielding at its extreme fibre when the column is initially crooked and elastically supported at the midheight. The intermediate support is to be designed so that it can provide the corresponding reaction. The carrying capacity of a column and the support reaction can be found by an elastic analysis on the assumption that failure occurs when the extreme fibre of the column reaches the yield point.

A chart is drawn for the design of a such column and its intermediate support. When the support and column sections are assumed, the spring constant ratio and the slenderness ratio can be calculated, and the ultimate load is found from the chart as the abscissa. The ultimate load thus found should not be smaller than the safety-factor times the working load. The corresponding ordinate of a reaction curve checks with the safety of the assumed support.

The results of this study indicate that the carrying capacity of a column is considerably lower when the lateral support has nearly the critical stiffness, which corresponds to the situation where the elastic support has the stiffness equal to that just necessary for the buckling configuration of an initially straight column to have an intermediate node, or less than the capacity in the case where supporting is perfectly rigid. This is particularly significant when the slenderness ratio is small. It is also seen that the support reaction may possibly become several times the design force of the AIJ provision, the value depending on the initial crookedness. The results of this study constitute one of the bases on which the one per cent of the AIJ Code provision is to be changed into two per cent in the near future.

Studies of the Third Miyakojima Typhoon
— Its Chracteristics and the Damage to Structures —

By Hatsuo ISHIZAKI, Ryozaburo YAMAMOTO, Yasushi MITSUTA,
Tatsuo MUROTA and Toshihiko MAITANI

Bulletin of the Disaster Prevention Research Institute, Kyoto University,
Vol. 19, Part 1, No. 153, August, 1969, pp. 45-85, (in English).

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On the Damage to Houses Caused by the Third Miyakojima Typhoon

By Hatsuo ISHIZAKI, Ryozaburo YAMAMOTO, Yasushi MITSUTA
and Tatsuo MUROTA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 449-461 (in Japanese).

Abstract

An expedition was made to Okinawa for the study of the Third Miyakojima Typhoon, which brought about serious damage there in September 1968. The meteorological characteristics and the damage to buildings were examined in comparison with those of the Second Miyakojima Typhoon, which struck the same region in 1966. The results are described in this paper following the checking rules which were suggested to UNESCO by the Ad Hoc Working Group on Missions to Areas Damaged by Severe Wind Storms.

The Third Miyakojima Typhoon was one of ordinary intensity for the northwest Pacific area, but the maximum peak gust of 79.8 m/sec observed in Miyakojima Isl. was one of the extreme values for Okinawa.

Severest wind damage was caused in Miyakojima and Kumejima Isl's. The damage to houses in Miyakojima Isl. was of 5.8% complete destruction but less serious than that caused by the Second Miyakojima Typhoon in 1966, because many of the houses that were destroyed in 1966 were reconstructed into reinforced concrete structures or repaired and made stronger.

The damage distribution appeared to be remarkably affected by the topography and features of the terrain. This was observed clearly and in complex aspects in the mountainous island of Kumejima, and was also observed even in the flat island of Miyakojima.

Damage to houses was studied statistically, and it is suggested that the complicated nature of damage can be clarified if an appropriate number of houses are studied as a unit. The relation between damage rates and maximum peak gusts was obtained at a range up to 80m/sec maximum peak gust.

Wind Effect Measurements on a Full Scale Tall Building and a TV Tower

By Hatsuo ISHIZAKI and Tatsuo MUROTA

Bulletin of the Disaster Prevention Research Institute, Kyoto University,
Vol. 19, Part 4, No. 166, March, 1970, pp. 37-44 (in English).

Abstract

The significance of wind effect measurements on full scale buildings and structures is stated, and an attempt to measure wind effects on a 22-story hotel building and a 160 m TV tower in Osaka City is outlined.

The measurements aim to provide knowledge about the nature of 1) city winds, 2) wind pressures on structures and 3) response of structures in winds.

The site of these measurements is on the northern edge of the most built-up area in Osaka. Buildings are crowded around the site but most of them do not exceed 30 m in height. The tower is a steel-trussed TV tower 160 m high, having square sections of 14 m × 14 m up to 100 m and 4 m × 4 m up to 140 m. It has two look-out platforms clad with windows at heights of 90 and 95 m. The hotel building is 22-storied and has rectangular plans of 35 m × 114 m up to the fifth floor and 15m × 88m up to the 22nd floor. The top of the roof parapet is 77 m above the ground. The construction is of steel-reinforced concrete (1–4F) and steel (5–22F).

Four three-cup anemometers are mounted on the tower 25 m, 50 m, 80 m and 120 m above the ground. Velocity pressures are also measured at 120 m and 102 m by Pitot-tube type pressure gauges. The gradients of the horizontal plane at 75 m of the tower are measured by clinometers. Bellow type wind pressure gauges were developed for the measurements and fifteen of them were arranged on the hotel building walls.

Some data for the strong wind of Typhoon 6909 were obtained on August 1969 and spectral analysis was made on the tower gradient responses.

Experimental Studies of Turbulent Transfer Processes in the Boundary Layer over Bare Soil

By Yasushi MITSUTA, Tatsuo HANAFUSA and Toshihiko MAITANI

Bulletin of the Disaster Prevention Research Institute, Kyoto University,
Vol. 19, Part 4, No. 167, pp. 45-58 (in English).

Abstract

A pilot experiment in the measurement of transfer processes in the boundary layer was made by using a sonic anemometer-thermometer and a fine thermocouple psychrometer. It was successful, and the observational technique used in this study can be well applied to further experiments. The main results of this investigation are briefly shown below.

1) The time change curves of the turbulent fluxes of momentum, heat and water vapor, are not the same in shape and show their peaks at different time of the day.

2) The evaporation from a small pan evaporimeter is almost three times larger than that estimated by the eddy correlation method.

3) The values of the eddy diffusivity of momentum are larger than those of sensible heat and water vapor by about three times in unstable cases and about 1.5 times in near neutral and stable cases.

4) The averaged values of the peak frequencies in the logarithmic spectra of the vertical and horizontal velocity components, air temperature and water vapor in unstable and very unstable cases are 7.6×10^{-2}, 3.6×10^{-2}, 4.6×10^{-2} and 5.6×10^{-2} in a normalized frequency respectively.

5) The dependency of the peak frequencies of the cospectra on the stability of the atmosphere is not clear in this study.

6) In unstable cases, the values of the cospectral correlation coefficient are almost constant and about 0.4 in the frequency range lower than 0.06 in the normalized frequency.

On the Vibration of a Steel Truss TV Tower in Wind

By Hatsuo ISHIZAKI, Tatsuo MUROTA, Changoo HUH
and Inhwan SUNG

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 411-418 (in Japanese).

Abstract

Wind effect measurements were made in Typhoon 6909 on a steel truss TV tower of 160 m height, which is located on the northern edge of the most built-up area in Osaka City.

Velocity pressure at 120 m and horizontal gradients of the tower section at 75 m were measured by a vane-type wind pressure gauge and two clinometers, respectively.

The motion of the tower was analyzed and power spectral density estimates of the gradient response were calculated. The following results were obtained:

1) the frequency of vibration is about 0.7 1/sec, which is close to the period of fundamental free oscillation.

2) averaged values of tower gradients were very small in comparison with the fluctuating components.

3) power spectral densities of the tower gradients were calculated for the frequency range of 3×10^{-3} to 2 1/sec. A clear energy concentration was found at the frequency of 0.15 1/sec in addition to that at the fundamental frequency of 0.7 1/sec. Some examinations about this energy concentration were made but the conclusion is not obtained.

Measurement of Turbulent Fluxes from a Moving Ship (2)

By Yasushi MITSUTA, Tatsuo HANAFUSA and Toshihiko MAITANI

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 419-432 (in Japanese).

Abstract

The method of direct measurement of turbulent fluxes over a sea surface from a moving ship proposed in the previous paper is tested by the data of the ocean expedition by R. V. Ryofu on the East China Sea in 1969. The results of the evaluation of each term in the correction equation of the ship movement show that the correction term of pitching motion of the ship is as large as the observed relative wind velocity component. The estimated values of turbulent fluxes are compared with the values estimated from the mast profile data by the bulk method, which are shown in the Table. The values of momentum flux coincide with each other but the values of sensible heat and latent heat obtained by the eddy correlation method are larger by three or four times than those by the bulk method.

The results of the ocean expedition by R. V. Hakuho at the same location in 1970 are also shown. The spectra of wind speed fluctuation were analyzed. The results show that there exist energy gaps in the range from 10^{-3} to 10^{-2} cps and micrometeorological peaks at about 2×10^{-3} cps, the frequency range of which is different from the frequency of ocean waves.

Table The results of analysis for Run 16 (1968).

Mast	Wind velocity	U_a	5.0 m/sec
	Temperature	θ_a	25.2°C
	Spec. humidity	q_a	19.0 g/kg
Sea surface	Temperature	θ_w	25.3°C
	Satur. spec. humidity	q_w	20.1 g/kg
Eddy corr. method	Momentum flux	$\tau_e=-\overline{\rho w' u'}$	0.35 dyne/cm^2
	Sensible heat flux	$H_e=c_p\overline{\rho w' T'}$	0.27 mcal/cm^{2}min
	Latent heat flux	$Q_e=L\overline{\rho w' q'}$	8.12 mcal/cm^{2}min
Bulk method	Momentum flux	$\tau_b=\rho C_d' U_a^2$	0.35 dyne/cm^2
	Sensible heat flux	$H_b=c_p\rho C_d'(\theta_w-\theta_a)U_a$	1.1 mcal/cm^{2}min
	Latent heat flux	$Q_b=L\rho C_d'(q_w-q_a)U_a$	25.1 mcal/cm^{2}min

Rainfall on the Walls of Buildings in Storms

By Hatsuo ISHIZAKI, Yasushi MITSUTA and Yuji SANO

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 433-439 (in Japanese).

Abstract

Rainfall on the walls of buildings in storms is studied. Rain water on windows or walls is forced into the insides of the buildings by wind pressure and causes serious damage. Observations on real buildings in the campus of the Shionomisaki Wind Effect Laboratory were made for about one year by the use of a specially designed wall rain-gauge.

The results show that the ratio of rainfall on the wall to the horizontal rainfall increases with the wind velocity component normal to the wall as shown in the figure. The proportional constant is nearly equal to the converse of the mean fall velocity of rain droplets, which means that the collision efficiency is almost unity for heavy rain on the buildings.

The maximum rainfall rate in Japan is about 56 mm per 10 min. If a heavy rain of this intensity is accompanied by a strong wind of 30 m/sec, the intensity of the rain on a vertical wall becomes about 23 liters/m^2/min. This value is much larger than that now used for the design criteria of curtain-walls.

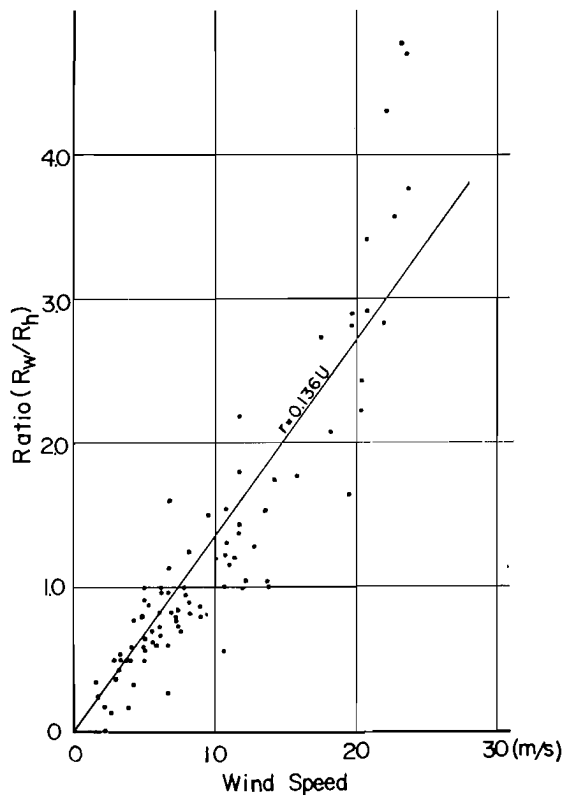

Fig. Dependence of the ratio of rainfall on the wall to that on horizontal ground on wind speed.

Comparative Observation of Anemometers

By Yasushi MITSUTA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 441-448 (in Japanese).

Abstract

The performance of the anemometer used in general weather observation is checked by comparative observations.

The propeller or cup anemometer, which is the so-called rotating type anemometer, is now widely used in general weather observation. The main problems of the anemometer of this type are: the threshold in low wind speed caused by friction, which is too large to ignore; and the non-linear response character in turbulent wind.

The threshold of the propeller anemometer is about 1 or 1.5 m/sec in non-turbulent wind tunnel flow. The effect of this threshold on the results of observations in turbulent natural wind was studied through comparative observation with a sonic anemometer, which has no moving parts and no threshold. The study results show that the frequency distributions of observed wind speeds are quite different in the low wind speed area, as shown in the figure. The relatively high occurrence frequency in low wind speeds of less than 0.5 m/sec or so, seen in the results of the propeller-type anemometer observation, is apparently caused by the threshold of the propeller anemometer because it is not seen in the results of sonic anemometer observation.

The comparative observation of cup and propeller type anemometers was made at Shionomisaki in typhoon winds. The results show that the over-estimation of mean wind speeds caused by the non-linear character of the rotating type anemometer is rather larger than that which can be estimated from the theoretical studies for four or three cup anemometers. And it it found that the propeller-type anemometer produces another kind of error in wind speed measurements in extremely turbulent winds caused by over-swing of the anemometer axis as a wind vane.

On the Aseismic Safety of Building Structures

By Ryoichiro MINAI

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 5-22 (in Japanese).

Abstract

In order to obtain reasonable aseismic design of building structures, it is necessary to estimate quantitatively the aseismic safety of such structures from the probabilistic point of view, considering the random nature of earthquake excitations and the random spread of the various parameters which define the mechanical properties, above all the final state of structures.

This paper deals with a reliability function defined as the probability of survival as a function of time, of elasto-plastic structures subjected to non-stationary random earthquake excitations, considering the random low-cycle fatigue phenomenon of structures composed of ductile materials.

To begin with, using the linear cumulative damage theory, the mean damage rate due to non-stationary random low-cycle fatigue of elasto-plastic structures is calculated in explicit form, following the methods presented by R.W. Lardner and J.B. Roberts, and using the exponent function type low-cycle fatigue function with respect to ductility ratio and the expected number of level crossings per unit time or the total expected number of peaks per unit time and the probability density function of peak amplitude in the non-stationary Gaussian random process. Then, the probability density function of the residual ductility ratio is expressed in the integral representation in terms of the probability density function of the cumulated damage and that of the critical value of damage and static fracture ductility ratio which describe the low-cycle fatigue fracture criterion together with a deterministic exponent.

Secondly, the reliability function of elasto-plastic structures subjected to non-stationary random earthquake excitations is approximately expressed in the exponential function type by using the expected number of crossings of the level corresponding to the residual ductility ratio per unit time, and the previously-mentioned probability density function of the residual ductility ratio.

Finally, by making use of the equivalent linearization technique obtaining the non-stationary, non-linear, random response which is an extension of the method of T.K. Caughey for the stationary, non-linear, random response, the reliability function of the single-degree-of-freedom oscillator having bi-linear hysteretic restoring force characteristics to a quasi-stationary random process is analyzed. It is shown that the reliability function is remarkably influenced by the type of low-cycle fatigue represented by the exponent and the static fracture ductility ratio and by the non-stationarity of earthquake excitations mainly expressed by their duration time.

Wave Transfer Functions of Inhomogeneous Linear Viscoelastic Multi-Layered Media

By Takuji KOBORI, Ryoichiro MINAI and Tamotsu SUZUKI

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 213-232 (in Japanese).

Abstract

In actual soil ground, even in individual layers the parameters of the soil vary according to the depth of the layer in question, and the variation of the properties in several successive layers may be represented macroscopically as an appropriate continuous function of depth. In this paper general expressions of the one-dimensional wave transfer functions of horizontally multi-layered ground, each layer of which is composed of an inhomogeneous (or sometimes homogeneous), isotropic, linear viscoelastic medium, are developed.

This paper is in three sections: (1) The conditions are derived under which the fundamental solutions of the wave equation of certain inhomogeneous media may be expressed in terms of the Whittaker function that contains trigonometric, exponential, and Bessel functions. These conditions are a system of nonlinear ordinary differential equations for the constitutive parameters of the medium and those arbitrary functions which are introduced conveniently for their broader applicability. The shear modulus and the density of several inhomogeneous media satisfying the necessary conditions are presented in the table with the fundamental solutions of their wave equations. (2) The analytical expressions of the wave transfer functions at an arbitrary point in a layered half-space, each layer of which may be either homogeneous or inhomogeneous, are derived to a vertically incident plane wave of the SH type at the bottom boundary adjacent to the homogeneous foundation medium. These expressions including the matrix multiplication are obtained by the method for determining the unknown constants appearing in the previously prescribed fundamental solutions of the wave equation from the boundary conditions. (3) Numerical examples are calculated for the case where the vertical variations of the parameters of an inhomogeneous medium are expressed as the function, $(1+\alpha\xi)^p$ (in which ξ=nondimensional coordinate, and α and p=arbitrary constants), and where its fundamental solutions are thus represented in terms of the Bessel functions.

Results of the numerical evaluation indicate that an inhomogeneous medium is a limiting representation of a multi-layered medium having an infinite number of homogeneous layers. Thus, if an inhomogeneous medium is supposed to be divided into several imaginary layers and also if each divided inhomogeneous layer is replaced by a homogeneous one having the average properties of the corresponding inhomogeneous layer, the wave transfer functions of the inhomogeneous medium can be evaluated approximately from the homogeneous layered medium, which has replaced it.

As an another example, the case where an inhomogeneous surface layer over the foundation medium has a shallow intermediate homogeneous layer is investigated, and the effects of the intermediate layer on the wave transfer functions of the whole system are examined in detail.

Vibrational Characteristics of Structures Considering the Effect of Ground Compliance

By Takuji KOBORI, Ryoichiro MINAI, Yutaka INOUE and Teruo KAMADA

Annuals, Disaster Prevention Research Institute, Kyoto University, No. 13A, March, 1970, pp. 251-263 (in Japanese).

Abstract

This paper investigates the effects of the dynamic characteristics of the ground on the vibrational characteristics of a structure coupled with that ground. The dynamic characteristics of the ground for rotation are simulated by an approximate transfer function of a rational type based upon the numerical results of Dynamical Ground Compliance. Combining it with the dynamic characteristics for horizontal translation obtained already, we consider the rocking motions of a rigid body and of a structure on an elastic ground and evaluate the fundamental frequencies and equivalent viscous damping ratios which are due to energy radiation into the ground, solving the characteristic equations for the system. These results are necessary for response analyses of a coupled structure-ground system subjected to earthquake excitations.

In the first part of this paper, the system which consists of a rigid body and a ground is dealt with. Considering the rotational effects of the body, it is found that fundamental frequencies decrease generally; but that the lowest fundamental frequency for a body light in weight and low in height increases slightly. Though an explicit damping mechanism is not considered here, the damping effects of the ground due to energy radiation are remarkable, and they depend on the weight and the height of the body.

In the latter part of this paper, the vibrational characteristics of a structure supposed to be one mass system of shear type which is coupled with the foundation and the ground are discussed and the following points are made:

(I) The fundamental frequencies of the coupled system become smaller with the rocking motion of the foundation.

(II) The dynamic effects of the sub-structure consisting of the foundation and the ground are different according to the ratio of the stiffness of the structure to that of the ground and the fundamental frequency of a structure on a soft ground decreases remarkably.

(III) The effects of the height of the foundation, though considered to be small in general, should not be neglected when the mass of the foundation is small compared to that of the ground.

(IV) The fundamental frequency ratio of the upper-structure to the sub-structure and the mass ratio of the foundation to the ground have a great effect on the damping ability of the system, and the smaller the height of the foundation, the larger the damping ability.

Earthquake Response of Structures Considering the Effect of Ground Compliance (4th Report)

By Takuji KOBORI, Ryoichiro MINAI, Yutaka INOUE and Teruo KAMADA

Annuals, Disaster Prevention Research Institute, Kyoto University, No. 13A, March, 1970, pp. 265-286 (in Japanese).

Abstract

A method of analyzing the nonstationary earthquake responses of an elasto-plastic ground-structure system is presented. The dynamical characteristics of the ground are represented by a transfer function, which is a second-order rational type function. It approximates numerically the dynamical ground compliance of a rectangular foundation on an elastic half-space. An above-ground structure is idealized, for simplicity, as a one-degree-of-freedom system, the restoring characteristic of which is supposed to be a bilinear hysteretic type. Considered that the soil-ground adjacent to a foundation mass may behave inelastically during strong motion earthquakes, an elasto-plastic boundary layer is supposed to connect the above-ground structure and the foundation mass system with the elastic ground. Thus, the interest of this response analysis is focused on the energy consumption in the subsystem, where the boundary layer under a foundation mass contributes to energy dissipation on account of the plastic yielding and the semi-infinite elastic ground has the effect of radiating seismic energy into the soil ground.

A set of band-limited white noise which has a finite duration-time is used as an earthquake acceleration excitation, and making use of an analog computer, the nonstationary response analysis is carried out for various sets of parameters of the ground characteristics and earthquake excitations. The effect of ground-structure interaction on the average of the maximum relative displacement responses for an excitation ensemble is discussed.

In conclusion: Ground-structure interaction has a significant influence on the transmission of excitation energy to the above-ground structure. The response of the above-ground structure is suppressed by the hysteretic energy dissipation of the boundary layer as well as by the energy radiation into the ground. This advantageous coupling effect of the ground may be much more anticipated for a relatively rigid structure on a soft ground and for earthquakes of a moderate intensity. However, when the intensity of an earthquake excitation increases to a certain extent, a large plastic yielding of the above-ground structure is caused by the filtering characteristic of the softer subsystem that amplifies a lower frequency component of the earthquake excitation energy especially.

Torsional Response of Framed Structures Considering a Yield Surface in Elasto-plastic Joints

By Takuji KOBORI, Ryoichiro MINAI and Teizo FUJIWARA

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 287-301 (in Japanese).

Abstract

It is inevitable to design a structure with some eccentricity and the responses of such an asymmetrical structure subjected to ground motion contain some components of torsional motion besides translational motion. So, at the sections of the frame members of such a structure, there exist several kinds of force, that is, two components of bending moment, torsional moment and axial force.

In this paper, nonlinear torsional vibration of an asymmetrical one-story building structure with elasto-plastic local joints has been analyzed considering the effects of interaction on yielding. The structural models are supposed to be two types of undamped systems; for idealized structure A, elastic limit rotations of local joints are taken to be equal, while for B, the elastic limit potential energy of each joint is taken to be equal. Meanwhile, a cosine wave and a typical earthquake record are taken as excitation patterns for the structure.

The following results are obtained:

(1) Maximum responses of the center of mass of the structure during ground motion are fairly affected by the effects of interaction on yielding, especially by that of axial force which seems to contain so-called P-Δ effect partially. Therefore, it is desirable to design the structure with effective aseismic members so as to restoring force characteristics being nonnegative in the plastic region.

(2) The torsional response for elasto-plastic behavior is larger than the response for elastic behavior, but is similar to the response for the behavior with interaction. On the other hand, comparing model A to model B, maximum torsional responses are resemble both models, but the ductility ratios of the local joints are quite different; the difference of aseismic safety between rigid columns and flexible columns for model B is less than that for model A.

On the Statistical Aseismic Design Determining the Optimum Dynamic Characteristics of Structure

By Takuji KOBORI, Ryoichiro MINAI and Masahiro KAWANO

Annuals, Disaster Prevention Research Institute, Kyoto University,
No. 13A, March, 1970, pp. 303-321 (in Japanese).

Abstract

This paper discusses the possibility of the statistical design of a structural system under optimum conditions for aseismic safety. To apply the statistical design method to structures, it is necessary to obtain the statistical and analytical expressions for structure responses considering the input and the output of the structure as stationary random processes. Here, the statistical information about structural dynamic behavior subjected to white noise excitation is obtained in the form of the spectral density and the standard deviation of displacement. On the other hand, the dynamic characteristics of the structure to be designed are given by the product of the stiffness distribution and the reference stiffness. As the optimum conditions for aseismic safety, the performance index and the constraint for the mean maximum response of the structure are considered. The performance index describes the degree of spacial uniformity of aseismic safety.

The optimum dynamic characteristics are determined so as to limit non-dimensional displacements or ductility factors within the allowable values and to minimize the performance index. In this case, the stiffness distribution is derived from the performance index and the reference stiffness is determined from the constraint for the mean maximum response, which may be one kind of cost function. So the purpose of the design method mentioned above is the synthesis of the structure to satisfy the necessary dynamic conditions and to minimize cost function. To examine the validity of the method, numerical calculation is executed for three-degree-of-freedom, linear, shear type system. As a result, the optimum stiffness distribution is found so that the standard deviation of all stories coincides closely with the spacial average of displacement. And the reference stiffness has a minimum value at the corresponding dynamic parameter which minimizes the performance index. So it is concluded that the statistical method is adequately applicable to the aseismic design of a structural system.

Vibrational Characteristics of Semi-Infinite Visco-Elastic Medium Due to Surface Excitations

By Takuji KOBORI, Ryoichiro MINAI, Tamotsu SUZUKI and Kaoru KUSAKABE

Reports of the Architectural Institute of Japan (KINKI Sub-Division), May, 1969, pp. 81-84 (in Japanese).

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Vibrational Characteristics of Semi-Infinite Visco-Elastic Medium to Surface Excitations of a Rectangular Area (Part 2)

By Takuji KOBORI, Ryoichiro MINAI and Kaoru KUSAKABE

Annuals, Disaster Prevention Research Institute, Kyoto University, No. 13A, March, 1970, pp. 233-250 (in Japanese).

Abstract

For this paper, we have investigated the vibrational behavior of an isotropic, homogeneous, semi-infinite visco-elastic ground subjected to vertical and horizontal harmonic excitations on a rectangular surface area, by using the treatment described in the preceding paper. It is assumed that the distribution of exciting forces on the rectangular area is uniform for both the vertical excitation and the horizontal one. The numerical results of the amplitude and phase characteristics of the displacement components both parallel to each exciting force and perpendicular to it are shown graphically, along two principal axes of the rectangular area on the surface and along the depth below the center of the rectangular surface area. The most remarkable results are summarized as follows:

(1) The amplitude and phase characteristics are a function of the exciting frequency.

(2) At any point on the surface of the ground, the amplitude and phase characteristics are a function of the width of the rectangular area, but at any point along the depth where there is some distance from the exciting area, they become independent of that width.

(3) Along the axes perpendicular to the exciting force, the amplitude decreases monotonously with the distance from the exciting area, but along the axis parallel to the exciting force, the amplitude has maxima and minima at regular intervals, which are concerned with the wave-length but not with the width of the rectangular area.

(4) When the ground consists of a visco-elastic medium, the deeper the distance from the exciting area is, the smaller the displacement amplitude becomes compared with that in the case of a perfectly elastic medium.

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